# AGRICULTURAL TECHNOLOGY AND REGIONAL ECOSYSTEM PROTECTION: THE ROLE OF PUBLICLY FUNDED RESEARCH

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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The Institute of Food and Agricultural Sciences (IFAS) of the University of Florida has recently expanded its research and education center in southwest Florida. A new $2.3 million building has been constructed and the number of full-time faculty is in the process of being increased from one to fourteen members. This dissertation utilizes the literature and empirical information to characterize the social and biophysical environment in the southwest region. The objective is to suggest ways in which research and extension may be made more responsive to the ecological concerns in the state and region.

An interactive adaptation process is proposed for agricultural technology and agricultural research institutions. The case study of southwest Florida suggests two potential

interrelated incompatibilities: 1) between high-input agricultural technology and the protection of the biophysical environment, and 2) between the production-oriented public research center and the broader social and institutional environment. Modern agricultural production has both stock and flow impacts on the ecosystem. Total stock of land available for natural habitats is reduced by conversion of land to citrus or other crops. Flow impacts occur on and off-site from the alteration of natural water flows due to drainage, irrigation, and the injection into the environment of an array of fertilizers, herbicides, and insecticides.

Historically, the national public research system has been linked to the promotion of chemical and energy intensive agricultural technology which has been shown to produce adverse environmental and public health impacts. Research institutions find themselves closely associated with agricultural commodity producers, and at odds with environmental regulatory agencies and groups. This places what may be termed "stress" on the technology and institutions because of conflicts between economic profitability and environmental protection goals.

# CHAPTER 1

# INTRODUCTION

## Overview

The University of Florida, through the Institute of Food and Agricultural Sciences (IFAS), maintains a statewide network of twenty-two agricultural research and education centers with a mandate to conduct agricultural research and extension programs in their assigned multicounty areas of the state. In southwest Florida, the center located at Immokalee and known as the Southwest Florida Research and Education Center (SWFREC) has been designated to work in Charlotte, Collier, Glades, Hendry, and Lee counties (Fig. 1.1). This center is in the process of being expanded from its previous status, as a small facility housing one researcher, to a much larger operation with modern facilities and equipment for twelve full time faculty who have joint research and extension appointments. Center administration attributes the center's expansion to the increased demand for agricultural research created by expanding citrus production in the region following recent freezes in central Florida (Arnold 1987). The relatively less populated interior of the southwest region is the only area left in Florida which has large

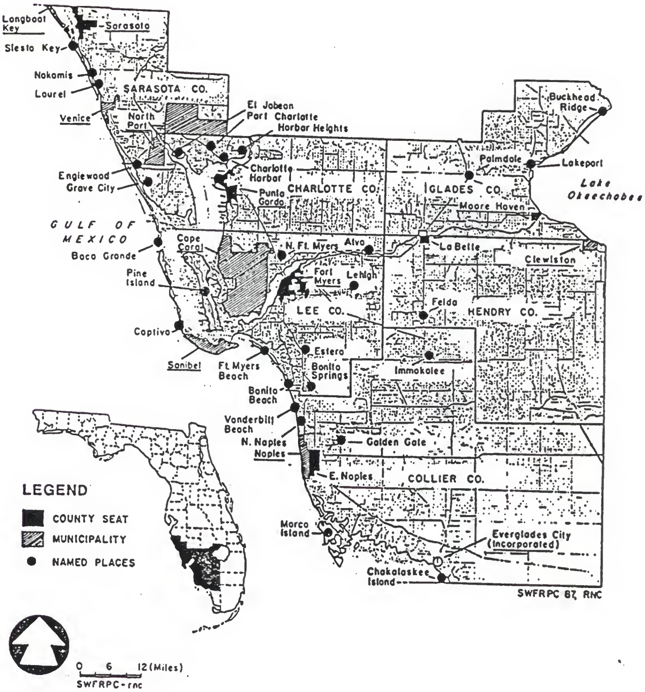


Figure 1.1. Map of Southwest Florida.

tracts of land potentially capable of being commercially developed.

There are three regional social or economic trends which are critical to understanding the dynamic operating environment of the Immokalee center. Agricultural expansion, urban population increase, and rising environmental concern, in their mutual incompatibilities, frame a problematic situation of both current and long term proportions for the establishment of a useful and viable regional research and education center. The 1987 Southwest Florida Regional Planning Council policy plan states:

> In southwest Florida, the needs of agriculture have often conflicted with the needs of the region's sensitive water and land systems. As environmental planning becomes more rigorous and directed, the constraints placed on agriculture are likely to increase unless these conflicts can be resolved by agricultural technology and practice. (p. 22-2)

Center administration stresses the role of the center in the provision of experimental data and other information which is needed for the critical regional task of balancing agricultural development and ecological protection.

Questions will be raised in this study as to whether historic and traditional approaches to the provision of publicly sponsored agricultural research are appropriate for this regional situation. It is suggested that substantial institutional and organizational innovation is required for IFAS and SWFREC to address emerging regional public concerns regarding the protection of the ecology. Similar questions about traditional research approaches and priorities are

being raised throughout the United States, in a variety of different social and geographic contexts.

## Problematic Situation

The five county area within the Southwest Florida Research and Education Center mandate includes approximately 3.4 million acres of land (5,400 square miles) or about 10% of the total land area of the state of Florida. For comparison, the region is somewhat larger than the state of Connecticut. According to 1987 figures, about one half million acres are in residential and urban areas while 600,000 acres are set aside in natural preserves, the largest of which is the Big Cypress National Preserve. The remaining 2.3 million acres are divided between cropland (796,010 acres) which includes established and improved pastures, native range (718,550 acres), and forests (761,639 acres). The major agricultural products are citrus, cattle, sugar cane, and vegetables.

Because of seasonal and spatial rainfall variation and the poor water holding capacity of the local soils, much of the land in crop production requires an irrigation system of some type (IFAS 1986, p. 398). Irrigation represents the largest single consumptive water use category, approximately 60% of total consumptive use statewide. Modern low volume irrigation systems have, to the present, been most readily adopted in regional citrus production. For a variety of economic and biophysical reasons, vegetable and sugar cane

production has remained largely in high volume seepage irrigation. Cattle have been raised on native range needing no irrigation and occasionally on irrigated pasture during periods of favorable economic conditions.

In 1984, southwest Florida's agricultural sector received gross revenues of $353 million with net farm income of $129 million (Bureau of Economic and Business Research 1987). Average net farm income for the region's 1,340 farm proprietors, who represent 3% of the state's total number of farm proprietors, was $96,688 with a range from $40,478 in Charlotte County to $147,710 in Hendry County. The figures for the remaining counties were $66,052 for Glades County, $82,536 for Lee County, and $146,641 for Collier County. These average income levels are relatively high for the state which contains a fair number of agriculturally depressed counties particularly in north Florida. With the general exception of vegetable growers and nursery operations, many of the region's producers could be classified as large in terms of land area. Average regional farm size in 1982 was 1,600 acres: 340 acres in Lee County, 1,427 acres in Collier, 1,562 acres in Charlotte, 1,807 acres in Hendry and 2,878 acres in Glades County. A small number of very large private and corporate landholders own in excess of 100,000 acres each. These landholders have become increasingly engaged in recent years in more intensive agricultural production by, for instance, converting ranch land to citrus groves. Finally, regarding agricultural

employment, there were 6,560 salaried jobs directly in the region's agricultural sector in 1984 with a much larger number of farm workers employed in low paying manual tasks such as orange harvesting. Specific information on the region's migrant laborer situation is difficult to obtain.

Against the general backdrop of the preceding discussion, the key regional trends noted above may now be amplified. First, and paralleling the development of the Southwest Florida Research and Education Center (SWFREC) itself, is a significant recent increase in regional agricultural production. The greater part of the production increase has been in citrus, specifically oranges. The other crops of major regional importance are vegetables, sugar cane, and cattle. Planted citrus acreage has increased from 51,760 in 1980 to an estimated 1987 level of 132,000 acres (Muraro and Mathews 1987). Based on water use permit applications received by the South Florida Water Management District, an additional 150,000 acres are currently planned for citrus development ("Move by Citrus to South Stirs Fear for Water" 1986). With continued favorable market conditions caused by freezes in the more northern areas of the state, the citrus expansion is expected to continue at least until replanted groves in central Florida return to production. Because of the comparative temperature advantage enjoyed by the southwest, economic incentives for citrus expansion could conceivably extend into the indefinite future if periodic freezes continue to damage crops in the more

northern regions. In regard to the other southwest regional crops, available data indicate vegetable production decreased somewhat from 45,040 acres in 1978 to 41,644 in 1982 (Southwest Regional Planning Council 1987) and is estimated in 1987 to have been about 55,000 acres. Sugar cane production has increased slightly from 68,500 acres in 1978 to 69,400 in 1985. Cattle production remained stable at 1.2 million acres over the 1978-1982 period. Updated ranch land figures would likely show a reduction due to conversion of acreage to citrus. The Cooperative Extension Service estimates that ninety-five percent of new citrus acreage was traditionally ranch land ("Citrus Acreage Doubles" 1987).

The second critical regional trend is the rapid increase in population. The implication of this increase is intensified competition between the residential population and the agricultural sector for natural resources, notably water. A recent incident of crop irrigation depriving residential users of water has been reported in the popular press. The report states that "heavy irrigation by a local farmer has left as many as 70 families without water for the past week, and it may be weeks before the underground water levels return to normal" ("Farmer's Thirsty Crop Dries Up Water Supply for 70 Families" 1988, p. B-3). This represents a possible emerging concern which could unite residential and environmental interests to pressure for change in agricultural technology.

Regional population has increased from 40,834 in 1950 to 487,688 in 1985 (Southwest Florida Regional Planning Council 1987). The increase has been particularly pronounced in the counties with coastal exposure (i.e. Charlotte, Collier, and Lee) which have together increased from 32,584 in 1950 to 458,063 in 1985. Population of the interior counties (Hendry and Glades) has grown from 8,250 in 1950 to 29,625 in 1985. The coastal population expansion is primarily attributable to the immigration of retirees from northern states. The population increase is the basis for significant real estate development which has been moving progressively toward the interior agricultural areas. Over the period 1980-87, two of the top three fastest growing metropolitan areas in the U.S. (Naples-49% and Ft. Myers-44%) are located on the southwest coast. Population projections show an expected decrease relative to historic growth rates. However, a doubling of the 1985 population of 458,063 to approximately 936,700 is projected by planning agencies by the year 2010.

Thirdly, there is a significant amount of regional environmental concern and activism from national and state citizen groups and from local chapters and organizations. The National Audubon Society, the Florida Audubon Society, the Nature Conservancy, and the Izaak Walton League are some of the many active groups. These groups have been effective in the region, particularly during the early 1970s, in obtaining federal and other funding for the purchase of natural preserve areas including approximately 600,000 acres in the

southwest region (Carter 1974). They were instrumental in stopping a proposed south Florida airport construction project in the Big Cypress area. Most recently, environmentalists have been involved in promoting a proposed land swap which would result in the addition of 108,000 acres to the Big Cypress National Preserve. They have also been involved in lobbying state regulatory agencies, particularly the water management district. The environmental groups regularly examine individual permit applications and oppose the granting of water use permits in cases where they are concerned about the ecological impacts of the proposed use.

The basic concern of environmentally oriented groups is that the regional ecosystem is very susceptible to disturbance, some possibly irreversible, from both agricultural and urban or residential development activities. The ecosystem contains areas of unique wetlands and a number of endangered plant and wildlife species including the Florida panther and the wood stork. Agricultural and urban development alters these natural habitats and displaces native species through the process of land clearing and through the change of natural water flows including the utilization of applied chemicals. The early residential development of southwest Florida was not planned. The region is the site of one of the most infamous Florida swamp land investment schemes which is located on 121,000 acres in western Collier County. This development includes 800 miles of roads and 171 miles of drainage canals on sensitive lands very similar to those set

aside in the Big Cypress National Preserve. Regarding the scheme, known as Golden Gate Estates, the "Water Resources Atlas of Florida" notes:

> The environmental disturbances which have resulted from the Golden Gate Estates canal system are substantial. They include the disruption of natural patterns of flow and major transfers of water from one basin to another, lowering water tables from two to eight feet, altering of the hydroperiod by two to three months, increasing annual runoff two- or three-fold, and causing much higher frequency of wildfires. (Fernald 1984, p.265)

The road and canal construction has dramatically altered the natural values of the land including off site impacts on neighboring natural preserves. The pervasive water control problems have made many of the residential parcels virtually uninhabitable.

Unlike many residential developers, agricultural producers in the southwest region have not established a poor environmental record. Before citrus expansion, the agricultural land was generally in low intensity use as land for cattle production on native range. The South Florida Water Management District has budgeted $500,000 for an ecological study on the impact of citrus conversion in southwest Florida. The eventual ecological implications of the projected substantial continued shift to citrus production are not now known, but the possibility for adverse impacts does exist on a number of fronts including water quality:

> Florida agriculture will continue to depend upon the use of pesticides in order to maintain minimal crop yields. The growing use of herbicides is to

> be expected as more efforts are made to control minimal soil loss. The use of new chemicals in Florida agriculture will carry the risk of such chemicals appearing in the groundwater. Agricultural interests and State regulatory agencies must be diligent in their efforts to insure that these chemicals do not result in a potential health threat to any aspect of the State's environment. (IFAS 1986, p.401)

In the Lake Okeechobee area of south Florida, agriculture has been accused of contributing to several ecological problems. These include the nutrient pollution of the lake and various negative impacts on the Everglades National Park. The Lake Okeechobee example presents a possible public perception problem for southwest regional agriculture.

In the general case of agricultural crop development, there is an apparent incompatibility in Florida. Artificial control of the water table and the water flows needed for agricultural production thwart the maintenance of the natural, and often high, water table necessary for the preservation of wetlands. Typifying the environmentalist view, Carter writes:

> The drainage of wetlands for agriculture has, beyond question, done more damage to the Florida environment than any other kind of development . . . where the terrain is as flat and low-lying as it is in much of Florida, drainage canals dug to serve one property owner may lower the water table on adjacent lands for miles around. Also, the disposal of excess water from farm lands into adjacent waters contributes to accelerated eutrophication: clear sandy bottom lakes filled with bass may quickly become algae laden and swarming with gizzard shad. (1974, p.26)

Producers have a different perspective of the impact of agricultural production on the ecology. They tend to stress the harmonious aspects of agricultural production and

ecological values including, for example, the presence of abundant wildlife in production areas. A major producer in Collier County recently developed innovative surface water management designs to help protect the ecology in citrus grove areas. These innovations received praise from regulatory agencies and environmental groups. Producers in the region have not been active, however, in publicizing and documenting their position and efforts regarding the protection of the ecology.

## Objective of the Research

The objective of this study is to provide theoretical concepts, empirical information, and applied analysis to assist SWFREC researchers in determining their role and research priorities with respect to the region's dynamic social and biophysical environment. The basic approach is to consider the regional social and biophysical influences on the generation of technology in the context of the maintenance and growth of the SWFREC. The interaction of the effects of agricultural expansion and technology with public institutions and regional organizations is specifically highlighted. Applicability of the present research is not limited to southwest Florida. The problems being encountered there are exemplary of broader problems concerning the role of the publicly funded agricultural research institutions in the U.S. The issue of the conflict between ecological

protection and agricultural development is also highly relevant to developing countries.

One of the main problems for the Southwest Florida Research and Education Center is how to best serve the "public interest" in light of the region's socioeconomic and ecological setting and the institutional mandate of the Institute of Food and Agricultural Sciences. When attempting to balance often incompatible priorities such as land productivity enhancement and ecological protection, the "public interest" is an enormously difficult concept to interpret. Researchers assigned to the center will be able to select from a wide array of possible projects within their own specialties and as members of project teams. The technological innovations and information that are developed by the center will be freely distributed "public goods." They will have cost-benefit effects on the center's regional constituents who are the taxpayers in the five county area. Benefits and costs will fall differentially on individuals and groups depending on how new technology affects, in the broadest sense of the term, their self interest.

The center's long-term viability will depend, to some degree, on its ability to meet regional needs and to deal effectively with interested regional groups. Those most directly affected by the center's activities would traditionally be the region's commodity groups. They require improved technologies to enhance productivity while simultaneously meeting the regulatory agency requirements for the

protection of the ecosystem. It is suggested here that the time of exclusive concentration on the needs of commodity groups is passed and an inclusive regional perspective is warranted.

## Organization of the Dissertation

The four primary components of the dissertation are a conceptualization of agricultural technology, a conceptualization of a research and education center, an application of the conceptual material to the case study in southwest Florida, and recommendations regarding the case study. Chapter 2 is devoted to a systems conceptualization of technology and technical change. A progression in the theoretical literature is shown beginning with technology considered as fully exogenous to the economic system, then to technology as directed by changes in relative factor prices, and finally to technology as influenced by a wide spectrum of socioeconomic and biophysical variables. In the systems conceptualization the technology is posited to have certain internal characteristics and rigidities so that it never perfectly adapts to the external socioeconomic and biophysical environment. It is critical to note that the task of research is conceptualized as being the improvement of that adaptive fit by creating new technologies and incrementally modifying existing ones.

Chapter 3 has two major purposes. First, it provides a discussion of the development of the national public agricultural research institution and problems that have evolved

with it over time. It is suggested that internal institutional rigidities have prevented the public research system from implementing innovative programs as national socioeconomic conditions have changed and knowledge about the biophysical consequences of modern agricultural production has improved. It appears that the basic institutional priority of increasing yields per acre has persisted despite agricultural overproduction and a host of ecological and sociological problems resulting from modern production methods. Priority attention to those ecological and sociological problems, which include environmental pollution and depressed rural communities, is in the literature called the "new agenda" for agricultural research (Batie 1988).

The second major purpose of the chapter is to present a conceptualization of a research and education center adapted from the agricultural economics literature (Blase and Paulsen 1972). It is a systems oriented perspective which envisions the goal of the research center to be its maintenance and growth through increasing funding inflows and technology outflows. The real world institutional and organizational rigidities discussed earlier in the chapter are viewed as limitations to increasing funding and technology flows. Relatively greater emphasis is placed on concepts which are relevant to a developing organization, such as the SWFREC, rather than on concepts more applicable to an organization with an established history. Some illustrative material from the case study is included.

Chapter 4 applies the major concepts found in the preceding chapters to the case study of southwest Florida. The interaction between technology and institutions is highlighted. Attention is given to the legislative rationale for the funding of the center, the initial establishment of linkages with commodity producer groups, and the early interactions with the regional water management district regarding the development of agricultural technology. The structure and incentives initially established at the center reflect the traditional "experiment station" paradigm which may be inappropriate in the longer term as greater public ecological concern comes to bear on agricultural technology. This organizational paradigm will be increasingly difficult to redirect as the organization develops and ages.

The final chapter presents a series of recommendations for possible consideration. Some relate to changes in center staffing, the composition of client groups, public-private cooperation in the funding of research, and the center's relationship with the water management district. A second group relates to the possibilities for further research in the social sciences which might be helpful in focusing research priorities at the center and in other situations where similar circumstances prevail. Finally, several suggestions are provided for further research in the discipline of agricultural economics.

CHAPTER 2

# AGRICULTURAL TECHNOLOGY AND TECHNICAL CHANGE

## Introduction

As outlined in Chapter 1 the regional problem with which the publicly funded agricultural research program must deal is that modern competitive agricultural production cannot occur without some disruption of the natural ecology. In our case study regional institutions and organizations are responsible for working out compromises between the untenable extremes of strict preservation of existing natural lands on one hand and the total individual freedom to develop those lands on the other. The case study discusses the interaction between the region's users of agricultural technology and two important regional organizations: the South Florida Water Management District and the IFAS Agricultural Research and Education Center at Immokalee.

This chapter provides a conceptualization of agricultural technology and technical change. This conceptualization then forms the basis for comprehensively considering the various interactions between the technology, the economy, and the biophysical environment which together give rise to the need for intervention often in the form of environmental regulation. The spatial and temporal relationship between

modern agricultural production and the biophysical environment makes it necessary to recognize the differences between the impacts of agricultural technology and those of various other kinds of technologies.

Agricultural technology is most productively viewed in an evolutionary systems framework wherein all inputs and outputs, both priced and unpriced, are considered. This includes both unpriced natural resource inputs (e.g. water) as well as unpriced outputs (e.g. residues and wastes). Agricultural technologies evolve and mature and eventually are displaced. In research planning it is important to know where a technology is in the technological life cycle. Historically, however, agricultural economists have focused on the movement of priced factors through a technological "black box" resulting in the production of priced outputs. Production basically is seen as an exchange phenomena and its characteristics are not researched, hence the term "black box." For environmental policy purposes, attachment to traditional neoclassical theory has resulted in simplistic and sterile analysis since, at an obvious minimum, markets and prices for many critical environmental variables do not and realistically will never exist. In fact, much of mainstream environmental economics involves demonstrating the economic efficiency rationale of natural resource and pollution "externality" markets. In a more realistic view negative "externalities" (e.g. water pollution) are considered joint products of the production process.

Given the fact that the treatment of technology and technical change is radically different depending on one's theoretical inclinations, it is difficult to offer clear general definitions. However, the definition of technology most often used in the literature relates to a "pool of applied knowledge." Technology may thus be considered a stock of applied knowledge with additions flowing in as a result of research and development activities. The additional flows may be considered technical change. Incremental technical change involves a minor adjustment to an exiting technology such as an improvement in fertilizer application methods. New technologies involve substantially new ways of doing things or ways of doing something not done before. Applied research typically produces incremental technical change which improves the adaptive fit of an existing technology to new or changing external circumstances.

There are two main components to this chapter. We first consider several approaches to technical change including the textbook, the induced innovation, and the systems theory conceptualizations. A progression will be seen in moving from the textbook view of exogenous technical change to induced innovation and then to a systems concept. The systems concept may be employed to lay out the environment, both socioeconomic and biophysical, which influences and is influenced by agricultural technology. An understanding of the textbook view is essential because it is a reference point for much of the discussion in the literature. The

conceptualization of technical change in mainstream economics as well as that of narrowly defined induced innovation (i.e. based on changes in relative prices) are shown to be inadequate for the purposes of this research.

A second major concern is to adopt a workable concept of the dynamic "behavior" of technology itself. Here we focus on some recent literature on the evolutionary nature of technology and how it responds or fails to respond to the socioeconomic and biophysical inducement agents. Researchers in this field have used a wide variety of concepts (e.g. "dominant designs," "technological regimes," and "technological paradigms") essentially to make the same point which is that technology has its own "organic" and evolving internal nature. Saviotti (1986), for example, has been very clear in differentiating between external influences and internal characteristics. A comprehensive catalog will be presented of key variables in the socioeconomic and biophysical external environment for the development of agricultural technology. But technology is not accurately viewed as simply reacting to external inducements. The internal nature of the technology, including the flexibility of its main characteristics, must also be considered. Interspersed in the chapter will be some illustrations of the theoretical concepts in light of the actual southwest Florida problem situation which was sketched out in the introductory chapter. Since citrus production is expanding most rapidly in the

region, that will be the focus of many of the specific comments.

## Textbook Technology

The textbook or neoclassical conceptualization of technology and technical change is fully embedded in the neoclassical theory of the firm and is therefore subject to the strong and weak aspects of that theory. The locus of technology is the production function and the development of new technologies or changes in old technologies are considered outside of the economic sphere. This strict division between the technical and the economic is fundamental to the neoclassical approach. The production function relates an entrepreneur's output to quantities of variable inputs. An assumption is made that the entrepreneur knows and uses the state-of-the-art technology so that output for given levels of inputs is maximized. The origin of the technology implicit in the production function has been called "manna from heaven" since it is the product of exogenous scientific research. This approach has also been called a "black box" concept since only the inputs and output are examined, but the actual workings of the technology are not. The neoclassical view may be summarized in the following textbook quotation:

> The entrepreneur's technology is all technical information about the combination of inputs necessary for the production of his output. It includes all physical possibilities. . . . The best utilization of any particular input

> combination is a technical not an economic problem. The selection of the best input combination for the production of a particular output level depends on the input and output prices and is the subject of economic analysis. (Henderson and Quandt 1980, p.66)

This theory is utilized as a basis for measuring the exogenous effects of technical change. The majority of neoclassical work in this area has been done on the influence of different types of technical change on an aggregate production function.

Graphically, the neoclassical production function may be represented by isoquants which relate the quantities of two factors of production to a given output level, often one unit of output is used and the result is called the unit isoquant (Fig. 2.1). The producer uses the factor combination represented by the tangency of the relative price line (p1p1) with the unit isoquant. The shape of the isoquants (i.e. convexity and continuity), an extremely important property which stems from assumptions concerning the production function, insures that a tangency point (e.g. T1) is achieved. The essential assumptions concerning the production function are that the function is single valued and continuous with continuous first and second order partial derivatives in a nonnegative domain (Henderson and Quandt 1980, p.66).

Using Figure 2.1, the distinction can be drawn between technical change, and factor substitution: a distinction which in practice is quite difficult. An exogenous change in the parameters of the production function which results in a

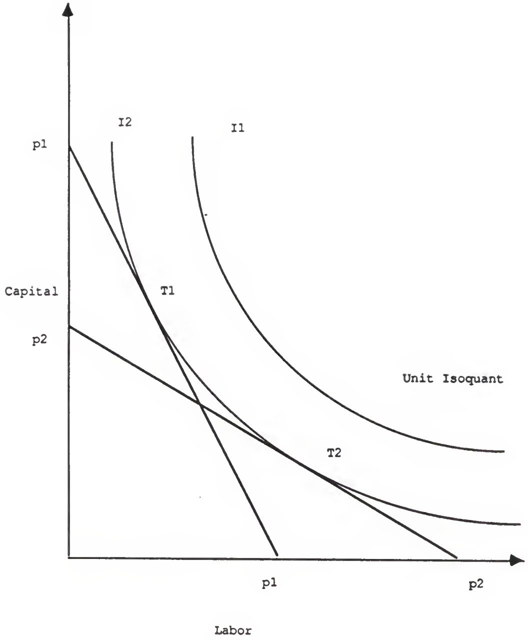


Figure 2.1. Technical Change.

shift in the unit isoquant (from I1 to I2) toward the origin is technical change. Less of at least one factor is used to produce the same level of output. A change, holding relative factor prices constant, is neutral if the isoquant shifts proportionately toward the origin and is factor saving if the proportion of a given factor needed to produce a fixed output is reduced. The notion of factor saving or using technical change is called bias and is central to tracing the effects of technical change through a socioeconomic structure.

In contrast to technical change, factor substitution occurs in response to a change in factor prices. In Figure 2.1 a relative price change which reduces the cost of labor relative to capital (from p1 to p2) leads to a tangency between the isoquant and the price line which uses more labor and less capital under the second price regime (p2). The difference between a shift along an isoquant (factor substitution) and a shift in the isoquant itself (technical change) is not easily distinguished in reality. The existence of knowledge over a broad spectrum of possible factor combinations or what has been called a "blueprint book" of all technical possibilities has been criticized. N. Rosenberg notes,

> Since - to introduce a primary assumption of my argument - why should technological alternatives representing factor combinations far from those justified by present prices be known? Why should a society, where the price of capital is low relative to that of labor, have available detailed information about labor intensive techniques of production? (1976, p.63)

Rosenberg finds that knowledge of only a small portion of the unit isoquant is consistent with reality. This highlights the problem of differentiating between a broad isoquant shift and a shift along an isoquant. Existing empirical evidence for any given situation shows only a change in factor use proportions. Other problems with the neoclassical formulation, such as in differentiating eco-nomies of scale from technical change, have been noted by various authors.

For purposes of this study it is important to note the basic terminology and graphic representation employed in textbook economics. Much of this will be carried forward to the next section. It is clear that neoclassical theory does not contribute substantially to the consideration of either the development of new technologies or the ranking of priorities for public agricultural research as a basis for technology development. The work done in the neoclassical tradition is focused on the effects of technical change, not the origins of it. As noted earlier, economic considerations are totally distinct from technical ones in this model. The model essentially "begins" after a given technology has been developed across a wide range of substitution possibilities. In contrast, the model of induced innovation is an attempt to incorporate the economic sphere with the technical sphere in a fairly straightforward extension of textbook neoclassical economics. It should be noted that the induced innovation literature has not been absorbed into textbook economics. The remainder of this chapter will move increasingly away

from the mainstream of economics and in a broad social science direction.

## Relative Prices and Induced Technical Innovation

The theoretical concept of induced technical innovation was initially proposed by John Hicks. It simply states that changes in relative prices cause inventions to be created which conserve the scarcest or most expensive factors. To quote directly: "The changed relative prices will stimulate the search for new methods of production which will use more of the now cheaper factor and less of the expensive one" (1963, p. 124). The "pool of applied knowledge" or technology is augmented in the course of the search for lower cost produc-tion. It should be noted that innovation is typically distinguished from invention. Invention is the creation of new products and processes while innovation is the adaptation of inventions for commercial use.

Referring again to Fig. 2.1, a change in relative prices from p1 to p2 causes techniques to be developed which would conserve capital since it has become relatively more expensive. This is an improvement in terms of realism over the textbook assumption which would imply that the techniques for more labor intensive production at T2 are instantaneously available. This induced innovation conceptualization addresses some of Rosenberg's criticism of the textbook presentation.

Historically, Hicks' original insight remained rather dormant in the literature until the 1960's when it was revived in the context of a debate surrounding the development of macro-economic growth models. The purpose of this line of research was to endogenize technical change in the macro-economic models. In the course of the macro-economic research Ahmad (1966) developed an essentially graphical conceptualization of induced innovation which has appeared prominently in the subsequent work of agricultural economists working in the field of technical change and agricultural development.

Ahmad's major conceptual contribution was the innovation possibility curve (IPC) as shown in Fig. 2.2. The IPC is an historic envelope type curve which is defined by the state of the basic sciences and relates to substitution between factors of production at different relative factor prices. The state of the basic sciences defines a set of production processes which could potentially be developed with the application of research and development financing by firms or public research institutions. The set of potential production processes are the unit isoquants contained by the envelope IPC. Firms and research institutions, i.e. innovators, spend money to develop cost minimizing technologies which allow production at relative price tangency points such as T in Fig. 2.2. Some elementary dynamics may also be introduced by showing the movements of the IPC over time (e.g. t to t+1

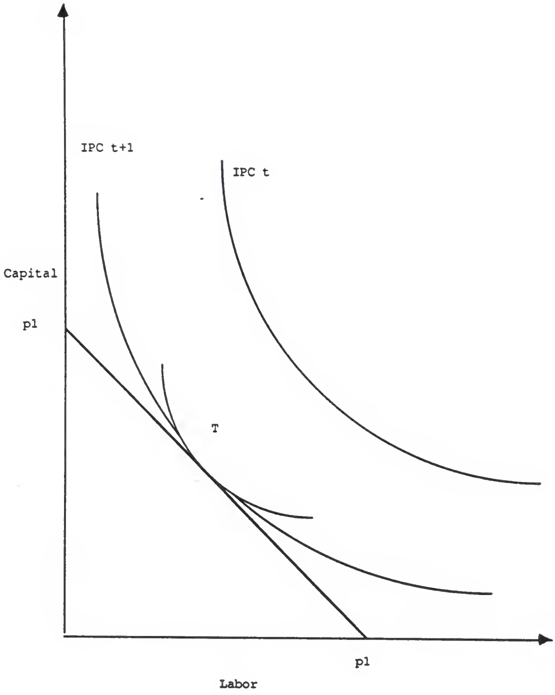


Figure 2.2. Induced Innovation.

in Fig. 2.2). As with the case of neoclassical production isoquants the IPC may shift toward the origin so as to favor the use of a given factor, i.e., a factor using bias. In sum, the set of possible factor combinations is circumscribed by the state of knowledge in the basic sciences. Within that set specific technologies are developed to minimize cost consistent with prevailing relative prices. Following in the Hicksian tradition the relative prices are the inducement agents.

Relative prices are not the only possible economic variables which might "induce" change. Other economists, for example, have focused on product demand as being the primary inducement agent. Combinations of the product demand and relative price research lines have also been attempted. It is not the purpose here to provide the details of that research and associated debates. What we are concerned with is demonstrating a progression, found in an eclectic mix of literature, beginning with exogenous technical change (i.e. neoclassical economics) and moving to a more comprehensive position of allowing economic, sociopolitical, and bio-physical variables to enter into the analysis as inducement variables. It is argued here that for planning purposes all relevant variables, economic and noneconomic, should be incorporated into the analysis. For other purposes however, such as the measurement of technical change, it is undoubtedly necessary to limit the number and nature of inducement variables. The measurements thus achieved are of

limited applicability in a broader social science research context.

## Agricultural Development and Induced Innovation

In the context of international agricultural development many agricultural economists, most notably Hayami and Ruttan, have employed the concept of induced innovation as the centerpiece for discussing a wide variety of issues including national agricultural research policy, the allocation of research spending, and technology transfer to developing nations. They summarize their position as follows:

> We hypothesize that technical change is guided along an efficient path by price signals in the market, provided that prices efficiently reflect changes in the demand and supply of products and factors and that there exists effective interaction among farmers, public research institutions, and private agricultural supply firms. Farmers are induced, by shifts in relative prices, to search for technical alternatives that save the increasingly scarce factors of production. They press public research institutions to develop the new technology and also demand that agricultural supply firms supply modern technical inputs that substitute for the more scarce factors. (1985, p.88)

Hayami and Ruttan have followed the Hicksian tradition of focusing on relative prices. They were the first to conduct extensive empirical studies and statistically demonstrate the importance of relative prices in the technological development of countries with different initial factor endowments. Their most dramatic results were found in the historical comparison of the well developed agricultural economies of Japan and the United States. For example, the land to labor ratio

was 1.74 hectares per worker in Japan versus 141 hectares per worker in the U.S. in the early 1960's. This is historical evidence that both countries developed technologies which allowed them to take advantage of the factors that were relatively more abundant: land in the case of the U.S. and labor in the case of Japan. Binswanger (1978) notes, however, that the relative factor price differences between the countries are much less than the actual factor use differences. In the context of the theory this implies possible distortions from the pure relative price driven model. It is precisely the examination of possible "distortions" of this, or of many purely economic models, which leads to a more comprehensive systematic or multidisciplinary analysis.

It is critical at this point to highlight a neoclassical economics assumption that has been carried along implicitly in the induced innovation model. The assumption is that the prevailing relative prices correctly, in a socially optimal sense, reflect the actual scarcities of the factors of production both in the present and the future. This assumption is open to criticism even as it pertains to reproducible factors but it is particularly questionable when considering natural resources, especially nonrenewable resources. The idealized process of competitive bidding assumed by the neoclassical economics literature is easily distorted in the real world by such things as labor unions, differential political power, and pervasive uncertainty in both human and natural systems. This point is most readily illustrated in

the context of real time where only the living bidders for natural resources are able to bid. In a dynamic temporal sense the prices of natural resources are always likely to be distorted. The issue is therefore not only the existence of distorting factors beyond the realm of relative prices but also the possible divergences of the relative prices themselves from unknown socially optimal levels, especially in the case of dynamic natural resource use. This raises the serious question concerning whether a successful test of the Hicksian induced innovation hypothesis implies the absence of distortions or whether the distortions are simply included in the relative prices themselves.

The pioneers of the induced innovation work on agricultural development have essentially maintained the relative price tradition but have highlighted the conditions that are necessary for the relative price characterization to be accurate. Hayami and Ruttan have been sensitive to the criticism that their focus has been narrow and have included in their work institutional influences and most recently cultural endowments as important factors in inducing technical change. In rebutting criticism Ruttan argues that the induced innovation theory does not imply that the unencumbered "invisible hand" can be relied on to direct technological development. He notes:

> The way in which resource endowments and final demand express themselves in factor/factor and factor/product price ratios is strongly influenced by the efficiency of market processes, by the responsiveness of political institutions, and by

> the existing structure of income distribution . . . If initial tests indicate a path of technical change that is inconsistent with relative resource endowments it immediately opens up a series of questions about the nature of the structural constraints that are inducing an inefficient path of technical change and the institutional innovations that would lead to a more efficient allocation of research resources. (1983, p.7)

If, however, price ratios are themselves largely functions of the social system, as posited here, it is difficult to discern how Ruttan sees "initial tests" possibly reflecting inefficient technical change. Pure relative prices would have to be determined by an omniscient social welfare maximizing observer and then compared with existing relative prices. In attempting to complete their general social science framework, Hayami and Ruttan cite the lack of complementary social science knowledge as inhibiting the further development of the induced innovation theory and thereby confining them to an exploration of "how far a strategy based on the straightforward extension of standard micro economic theory will take us in the the analysis of both technical and institutional change" (1985, p.114).

## Technical Change and the Social System

Several agricultural economists working with the concept of induced innovation have analyzed an expanded array of potential inducement or change agents. These involve social structures as well as traditional economic variables including relative prices. The most comprehensive social system framework has been developed by deJanvry (1978) and has been

utilized and further refined in the writings of a number of other researchers. In general, deJanvry does not disregard the effects of relative prices but sees the distortions from the pure relative price induced innovation model as pervasive and themselves worthy of study. For the purposes of this research the deJanvry framework will be used to represent the social system portion of the the overall system. To the social context will be added a conceptualization of the bio-physical environment for technical change in agriculture as drawn from the work of Georgescu-Roegen and others. A brief summary of the deJanvry model follows. It is drawn primarily from the original work (1978) and from Ruttan (1982).

The deJanvry socioeconomic model (Figure 2.3) seeks to explain the dynamic interactive supply and demand of technical and institutional innovations as a process of "circular and cumulative causation." Specific additions to the pool of applied knowledge are made in the course of ongoing social and political dynamics and not through a process linked to a detached reaction to relative prices. deJanvry disaggregates the human actors into interest groups which highlights the need in the course of applied analysis to correctly identify homogeneous groups. Farmers, for example, may vary greatly in their needs for and benefits from technology particularly with respect to scale of operation. Farmers often must begrouped by size or some other characteristic (e.g. education) for accurate analysis. The deJanvry model includes specificroles for the socioeconomic structure, the

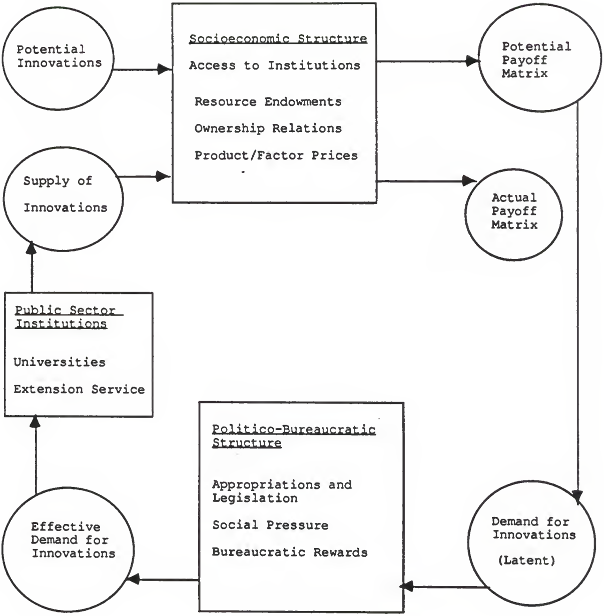


Figure 2.3. Social Structure and Technology
(Adapted from deJanvry, 1978).

politico-bureaucratic structure, and the innovation producing institutions such as the agricultural research and education centers in Florida.

The central construct of the deJanvry model is the "payoff matrix" which is defined as the array of expected monetary gains or losses which each interest group or individual expects to receive from possible alternative innovations which might be developed. Those possible alternatives are defined by the position of Ahmad's innovation possibility curve (IPC) in factor space as discussed above. This can be envisioned as a listing of potential public goods down one side of a matrix with the different interest groups listed across the top. Actual benefit entries in the matrix could be monetary but conceptually could also include simple qualitative descriptions of the effect of each technology on each interest group. Alternative technical innovations possibilities vary across commodities and regions and in their factor using biases. The breakdown of interest groups would, of course, depend on the specific situation under consideration. Possibilities for the southwest Florida case study include commercial farmers, agricultural workers, private input suppliers, government agencies, and environmentalists.

deJanvry considers the products of the innovation producing institutions to be public goods. The latent demand for public goods is derived from the expected payoff matrix. The formation of potential payoff expectations is conditioned

by the interactions and linkages of the research system and the various social groups. Latent demand is converted to actual demand through the political and bureaucratic structure. Key battle grounds for converting latent to actual demand include: 1) the social pressure system wherein groups lobby for attention to their latent demands, 2) the electoral and bureaucratic reward system wherein votes are sought for specific political commitments, and 3) the legislative system which translates those commitments into appropriations and laws. Latent demands become actual demands when public resources are allocated for innovation development such as is conducted at research centers.

The relative power of different social interest groups within the political bureaucratic structure is crucial for a group to acquire the supply of the sort of innovations in which it is interested. Within the innovation producing institutions (e.g. agricultural research and education centers), the state of scientific knowledge is conditioned partly by previous allocations of physical and human capital as well as the newly acquired resource allocations. Both types of allocations help determine the possible achievements in any line of research. deJanvry notes that the nature and structure of the research organization is important in how effectively actual demands are handled.

The actual supply of innovations leads to actual payoffs to interest groups through the socioeconomic structure. Conceptually, the sum of entries in the actual payoff matrix,

some of which may be negative, represents the total benefits produced by the research organization divided up by interest groups. For agricultural technology, actual payoffs and distribution are affected by 1) yield effect, resource using bias, and resource substitution effects, 2) the diffusion effect determined by the type of technological innovation and the position of the social groups in the socioeconomic structure, and 3) the relative prices that influence the economic value of the physical and diffusion effect.

The value of the deJanvry model is that it provides a comprehensive basis for looking at technical change in its full social context. In a theoretical sense, technical change in this model is not directed by price signals from some idealized market situation but is a function of real relations of political and economic power, the legal system, government bureaucracy, and importantly for our purposes, the "politics" of public research institutions and organizations. These structural concepts will be retained for the present research in order to illuminate the case study situation. In contrast to deJanvry, Hayami and Ruttan focus largely on relative prices and must impose the side conditions that the potential distortions (e.g. power) and distorting institutions (e.g. government bureaucracy) act benignly to preserve the purity of relative prices and their relationship to actual factor scarcity. That contrast is indicative of difference between the neoclassical tradition (Hayami and Ruttan) and the tradition of political economy (deJanvry).

deJanvry has made a very important expansion of the induced innovation concept yet this model is not comprehensive as it stands for the problem under consideration in this research. The deJanvry model was primarily developed for analyzing historic problems revolving around the perceived lack of appropriate technology for some or all of the farm population in Third World countries. In his empirical case work on Argentina, for example, deJanvry effectively demonstrates the existence of an excessive labor saving bias and lack of attention on the part of research institutions to the latent demand on the part of small farmers for land saving technology.

The deJanvry model was not developed explicitly for consideration of agricultural development and ecological conflicts although it is clear, for instance, that some environmentalist groups have latent demands for a certain types of ecology preserving technology. Many such groups, however, have latent demands for no agricultural production, i.e. strict ecological preservation. As will be seen later, it is crucial to understand the concerns of interest groups and bring them into the research planning process. In addition to attention to interest group influences, deJanvry's conceptualization of the role social structures and institutions in technology generation is extremely important. As a complement to social structure analysis of deJanvry the explicit inclusion of biophysical variables,

involving a more realistic conceptualization of the nature of technology, will now be added.

## Technical Change and the Biophysical System

Agricultural production draws inputs from and deposits wastes in the natural environment in a way that is fundamentally different from other types of technology and production. Headley notes that "external effects resulting from methods of agricultural production that extend to the natural environment are inextricably linked to application of technology to farm production" (1975, p.176). A comprehensive look at technology and technical change in agriculture must include the interactions with the biophysical system through addressing the physical character of production. In a way analogous to the socioeconomic system, variables in the biophysical system also induce or direct technical change. Due to an historic concentration on prices, stemming from the dominance of the neoclassical paradigm, economists and agricultural economists working on production related and environmental topics have generally trivialized or disregarded the biophysical system in their work and most continue to do so today. In a strident and widely quoted 1972 article praising the neoclassical approach to environmental problems Beckerman states:

> By comparison with real problems, the problems of raw material exhaustion or pollution are minor diversions, and they present relatively few difficulties, as far as devising the correct

> solution is concerned, and provided one does not aim at perfection. (p.344 )

In marked contrast to Beckerman, other contemporary researchers, using different theoretical principles, saw the situation very differently. Headley writes:

> It is time to treat the external effects of producing and consuming activities as very serious, massive problems of resource allocation rather than handling them as unusual difficulties that can be handled one by one and forgotten. (1975, p.173)

In recent years environmental concerns have increased interest in finding ways to produce food with lower harmful environmental effects. This research usually falls under the headings of sustainable agriculture, alternative agriculture, and low-input agriculture and explicitly includes environmental impacts which are no longer viewed as minor concerns.

It is fairly easy, at least conceptually, to include the biophysical environment and its interaction with technology and technical change in the present framework. Beginning with the neoclassical priced-based framework we must look at the input-output commodity production relations and expand the neoclassical conceptualization to include all inputs (e.g. solar energy, water) and outputs (i.e. wastes). The assumptions made in the literature are that unpriced natural resource inputs are "free gifts" of the environment and unpriced outputs represent the "free disposal" of wastes. Perrings has developed, at the macro level, an extensive exposition of the implications of using the "free gifts" and "free disposal" assumptions. Those assumptions are implicit in most neoclassical economic theorizing and practice even

though they run counter to fundamental physical laws such as those of the conservation of mass and energy. Such assumptions allow the neoclassical model to operate in its static non-evolutionary framework where wastes from production processes do not return to the system and cause it to evolve over time. Perrings notes:

> If these assumptions are made, it is necessary to consider neither the limits to growth nor the evolutionary nature of the system. It is of some interest, therefore, that the free gifts and free disposal assumptions have been the cornerstones in the theory of the time behavior of economic systems. Only by ignoring the physical foundations of economic systems has it been possible to generalize the static equilibrium results of the Walrasian system to the dynamic case. (1987, p.8)

Perrings stresses that the neoclassical "externalities" (e.g. pollution) are in fact a fundamental part of the economic-environmental system and that investment in the economic sphere is functionally related to the depletion of environmental resources (stocks) and the pollution of environmental processes (flows).

Turning specifically to agriculture the actual physical processes involved in agricultural production are highly nature and time dependent and have extensive spatial requirements (e.g. one acre per 100 trees in citrus). To view agricultural production in neoclassical terms as an instantaneous "exchange" of priced inputs for priced outputs, within a technological "black box," is a limited perspective ignoring the clear dependency on time and nature. This dependency is much stronger in agriculture than in a factory

process. Application of the limited neoclassical perspective has often kept agricultural economists from anticipating, understanding, and interacting with the environmental problems generated by modern agriculture.

Georgescu-Roegen has worked on clarifying the dynamic production process which he differentiates from the neoclassical exchange conceptualization. In Georgescu-Roegen's scheme there are funds and flows of both inputs and outputs. He notes that "the factors of production can be divided into two categories: the fund elements, which represent the agents of the process, and the flow elements, which are used or acted upon by the agents" (1971, p.230). He goes on to clarify that the funds are the "material base" of the process while the flows describe the changes achieved with the help of the base. The funds and flows are comprehensively catalogued as follows:

> For funds we may take our cue from the Classical division of production factors and distinguish them into Ricardian land (L), capital proper (K), and labor power (H). Among the flow elements we may distinguish first the inputs of the so-called natural resources (R) - the solar energy, the rainfall, the "natural" chemicals in the air and the soil, the coal in the ground, etc. Second, there are the current input flows (I) of the materials which are normally transformed into products and which come from other production processes - the lumber in a furniture factory, the coke in a foundry, etc. Third, there are the input flows needed for maintaining capital equipment intact (M) - lubricating oil, paint, parts, etc. Fourth, there is the output flow of products (Q). And, finally there is the output flow of waste (W). (1971, p.232)

Each of these variables is a function of the length of time that the process runs and are interdependent producing the following functional :

$$Q\ (t)=F\ [R\ (t),I\ (t),M\ (t),W\ (t),L\ (t),K\ (t),H\ (t)] \quad (1)$$

Georgescu-Roegen stresses the importance of time which in agricultural, as opposed to in factory production, is related to the dependence on nature. Certain natural inputs have to be "waited for" during which time some factors of production must remain idle. It is therefore difficult, for example, to maintain capital equipment fully employed in agriculture. The timing of the use of the factors is dependent on the biological properties of the given product.

The preceding paragraph provides us with one of the few examples in the economics literature of dealing directly with the physical aspects of production; this encounter is extremely important for our purposes. When moving into previously natural areas, citrus production technology installs a fund base through land clearing and tree planting thereby changing the natural stocks and flows of the existing landscape. When the agricultural production process begins, it uses free nature inputs (solar energy, soil fertility, water) along with normal priced inputs (seeds and fertilizer) to produce priced outputs and various types of waste. Wastes or residues figure prominently in most environmental conflicts.

Wastes are whatever physical inputs or parts of those inputs that are not incorporated into the output. In this regard Georgescu-Roegen states,

> Since by consolidation all flows between production and consumption units must cancel out, the global picture includes only two flow coordinates: an input flow from nature and an output flow of waste. As far as the material elements are concerned, the economic process simply transforms natural resources into economically valueless waste. (1976, p.97)

In agriculture, the waste component is critical particularly in the case of chemical inputs but various types of agricultural garbage (empty containers, plastic mulch) are also important. Waste is often not limited to a production site but is mobile in the soil, water, or even air. While some types of waste naturally decay, disposal procedures (e.g. burning) for other waste can amplify negative ecological effects. Waste (e.g. residual pesticides) may accumulate in soil or water bodies and be undetected until some biological threshold is reached whereupon it becomes a major public concern.

As can be seen from the sketchy illustrations made above the use of flows and funds provides a robust conceptualization of agricultural production. Under a given technology, different commodities and levels of output require certain types and sizes of funds and different flow rates of free nature and produced inputs. A change in technology therefore alters the funds and flows required for commodity production. The fund base for some types of agricultural production need

not be radically different from the natural ecology as in the case of cattle production (i.e. low capital, labor, and land modification requirements). Free nature and produced input flows in the case of cattle production may be fairly similar to the natural flows. Water, which will be discussed relative to the case study, is affected by production technology, first as a natural fund in qualitative and quantitative terms, and second as a flow used in natural and other off-site production processes. The joint product of output always includes at least some waste. By carefully considering the unique physical processes of modern agricultural production we may begin to see the close link between economic activity and the ecosystem.

## Systems Coevolution and Technology

Perrings' work on the integration of economic and physical processes referenced above follows in the tradition established by Georgescu-Roegen who was the first to seriously apply physical laws, specifically the laws of thermodynamics, to economics. Both Perrings and Georgescu-Roegen emphasize the evolutionary nature of the economic system. They portray the neoclassical conceptualization as being static and mechanistic, dominated by the metaphor of classical physics. In economics, and to a much lesser extent in agricultural economics, there has been some research which has utilized the evolutionary metaphor to describe the

economic system and in particular to characterize the nature of the firm (e.g. Alchian 1950).

In spite of the interwoven relationship of agricultural production with its biophysical environment few agricultural economists have attempted to employ Georgescu-Roegen's insights or other biological metaphors in agricultural economics research. One notable exception is Norgaard who has developed what he terms a coevolutionary perspective on the relationship between social and ecological systems. He defines the concept as follows:

> Coevolution in biology refers to an evolutionary process based on reciprocal responses of two closely interacting species. . . . The concept can be broadened to encompass any feedback process between two evolving systems. For agricultural social and ecological systems, man's activities modify the ecosystem while the ecosystem's responses provide cause for individual action and social organization. (1984, p.528)

"Man's activities" which "modify the ecosystem" in the preceding quotation need not be exclusively the function of technology. Human population increase is a particularly important example of that. Norgaard continues with specific relevance to our problem situation in the present research:

> While monocultural systems brought increasing returns to scale with mechanization, their ecological instability encouraged the development and use of agrochemicals and of risk spreading institutions. Similarly, ecosystem responses to agrochemicals have led to new pesticide and water pollution regulatory institutions as well as new research programs in agricultural experiment stations. (1984, p. 530)

To return to Georgescu-Roegen's characterization, the agrochemicals in the preceding example are flows in the commodity

production process which disrupt the natural system resulting in social pressure to mitigate the disruption. This type of multiple interaction results from an economic incentive to produce with agrochemicals, causing a reaction of the ecosystem and the eventual need for institutional intervention. This is central to much of the social conflict over the environment.

Recent work in biology has extended the biological concept of coevolution beyond the relationship of two species or two systems with each other to include the coevolution of an organism and its environment. The proponents of the "dialectical" evolutionary theory state:

> The factual difficulty of formulating evolution as a process of adapting to preexisting problems is that the organism and the environment are not actually separately determined. The environment is not a structure imposed on living beings from the outside but is in fact a creation of those beings. . . . The metaphor of adaptation must therefore be replaced by one of construction, a metaphor that has implications for the form of evolutionary theory. (Levins and Lewontin 1985, p.99)

The general perspective that we are adopting here is to look at technology as an organism and the coevolving socioeconomic and biophysical environments as the environment for the evolution of technology. Though there are many variables that are prominent in the interaction of the biophysical and socioeconomic systems (e.g. population), the focus is on technology as the interface between the systems. In contrast to the coevolution of plants and animals with their natural systems, there is some degree of conscious human social

control which can be achieved over the evolution of technology through the modulation of human activities in the socio-economic sphere. As can be seen by the great complexity of the situation, however, the degree of social control may not be very great using traditional policy tools.

There is nothing magical about the selection of a metaphor. The test of a metaphor is in the quality of insights it produces. Nelson and Winter (1982) in their work chose an outdated concept of evolution because it fit their purposes better. It is important to note the danger in setting out this type of systems analysis because it can readily become unwieldy and muddled with complex systems and many variables all thought to be evolving together. At the same time, however, the more one attempts to delve into the complexity of the situation the less confidence one can have in such models as the relative price form of "induced innovation" which relies on a simplistic conceptualization of the technological innovation process.

## Evolutionary Technology

There is a small fringe group of researchers currently engaged in studying technology in an evolutionary framework. It needs to be forcefully stressed that this work is at a very rudimentary and untested stage but it has been used effectively in case studies. Those who are employing the evolutionary metaphor include among others Nelson and Winter, Clark and Juma, Dosi, and Saviotti. While generally similar

in presentation, each of them has his unique concepts and tends to use a distinct vocabulary with such terms as technological "paradigms"(Clark and Juma), and "regimes" (Nelson and Winter) being examples. None of this research has been specifically carried out in relation to agricultural technology so for our uses there is no obvious selection among the evolutionary oriented writers. Saviotti's "Systems Theory and Technological Change" (1986) is, however, most in keeping with our interest in the use of biological metaphors and can be seen as including the concepts noted above (i.e. "paradigms" etc.). Therefore, Saviotti's work will be the primary source for this section.

Saviotti begins by conceptualizing technology itself as a complex system which has an internal structure, an external environment (e.g. in our case the socioeconomic and biophysical environment), and a set of goals. He posits a set of internal characteristics called "technical characteristics" and a second set of characteristics called "service characteristics" which accrue to the users of the technology. The technical characteristics must be changed in order to change the services of the technology. The internal structure is then seen as adapting to the external environment subject to the maintenance of essential internal variables. The essential variables remain qualitatively or quantitatively unchanged while the other adaptive variables absorb the change in the external environment similar to what occurs in temperature regulation in animals. The evolution of a

technology with a set of essential variables intact is what the other authors refer to as a technological "trajectory" or a technological "guidepost." The outer environment includes all possible external systems but in practice may be narrowed to a local environment or habitat. The goals of the technology system are based on whatever tasks the technology is supposed to accomplish (e.g. grow citrus).

In general, then, what is hypothesized to occur is an imperfect matching between the internal characteristics and the external environment with that process changing the services of the technology. When the external environment is fairly static then fine tuning of the internal characteristics of the technology takes place. This phenomenon is the one most often observed and documented in technological case studies where incremental improvements are made over time to a basic technology (e.g. the evolution of the farm tractor). With a rapidly changing external environment, however, radical changes to the internal characteristics may be needed. It is possible that the technology cannot adapt to the new external environment and may be replaced or be focused in new directions.

The interactive nature of the conceptualization implies that technology can change and be changed by the environment. Saviotti states that "changes in the environment can take place independently of the technology, such as a rise in oil prices, or they can be the direct result of the evolution of the technology itself" (1986, p.776). Of relevance to our

case, Saviotti notes that if the internal characteristics evolve to produce neoclassical "externalities" (e.g. pollution) then the system response will be to "induce externality suppressing regulation which in turn increases externality suppressing technical change" (1986, p. 777).

One of the most important points to stress in Saviotti's work, and in that of the others mentioned above, is that there is rigidity in the internal characteristics of a technology so that it does not instantly and completely adapt to the changes, especially radical ones, in the external environment. The rigidity comes from the necessity of maintaining the essential variables in the technology's internal environment. The spectrum of potential technical change with the same essential variables is much more limited than typically expected. For example, in reference to pressure resulting from changes in market conditions and opportunities Dosi notes this "does not imply by any means an assumption of malleable "ready to use" alternative technological paths, or, even more so, instantaneous technological responses to changes in market conditions" (1984, p. 21). Clark and Juma employ different forms of biological analogy (e.g. niches, DNA, etc.) than Saviotti does but they emerge at a similar conceptualization:

> The range of technological systems is narrowed down through a selection process that attempts to match the adaptive parameters of the system to key features of the external techno-economic environment. The increased matching of these parametric sets may be viewed as an increase in techno-economic performance. However, there is no

> technological system that is perfectly adapted to the environment or has the ultimate techno-economic performance. This is partly because of the limitations in the internal structure of the systems themselves and partly because of the constant changes that occur in the external environment. (1987, p.176)

The notion of internal rigidity of technology can also be expressed in more traditional terminology as Headley does in the case of agricultural technology:

> As technology has been adopted in agricultural production, it has tended to become a package of technically complementary inputs within a narrow range of substitution between inputs within the package. . . . Any policy action that alters the use of one or more of such inputs would change the production function, as opposed to moving to a different point on the same function. (1975, p. 165)

It is clear then that solutions to social conflict stemming from the use of a technology must take a much more detailed and complex look at the technological system. Simplistic solutions, such as "eliminate the use of pesticides," often imply the need not for a minor adjustment but for a whole new technology and a new technological paradigm, regime, or trajectory.

## Agricultural Technology and Its Environment

We have attempted to weave some disparate threads from the literature to provide a comprehensive context for discussing technical change in agriculture. The writings of deJanvry and Georgescu-Roegen taken together help conceptualize the theoretical environment for the evolution of a technology. The deJanvry model provides a general social

system context and includes the economic variables that have been the focus of the mainstream of induced innovation writing. The use of the fund and flow concepts of Georgescu-Roegen brings the biophysical relation between agricultural production and the ecosystem into the model. The works of Saviotti and others develop what the notion of evolutionary technology means. There is a great deal of fluidity in this characterization and some of the traditional terminology (e.g. constraints) has been avoided. The mental image of technology being projected is that of an imperfect and changing ball (i.e. the technology) finding its way through a complex uneven terrain (i.e. the environment) with all sorts of action and reaction taking place. If evolutionary conceptualizations are to be seriously utilized, the type of underlying thinking of researchers must be changed away from the deterministic and mechanistic models favored in the economics profession.

There are a number of different ways that the deJanvry, Georgescu-Roegen, and Saviotti material could be drawn together. Here we choose to focus on the fund-flow model of Georgescu-Roegen summarized in equation (1) and show how the other elements relate to it. The technology underlying equation (1) is simply the applied knowledge that combines a given set of funds and flows to produce the product and associated waste. The technology can be seen as evolving when differential use of the funds and flows change over time. The evolution of the technology is bounded by the biophysical

limits (e.g. a citrus tree needs a minimum of X amount of light) and by the limits of the social system which may proscribe the use of certain factors or the emission of certain wastes. Within the biophysical and social bounds the matching of the internal characteristics to the external environment occurs. As deJanvry notes, all sorts of social institutions influence what is demanded of a technology. In developed economies, economic viability must be maintained in the course of the internal-external adjustment of a technology. The matching is likely to be more complex and noneconomic in traditional societies.

The specific technology then may be defined by its characteristics which are the funds and flows it utilizes in production. In Saviotti's terminology there are essential fund levels and flow rates to stay within a given technological paradigm or direction. Incremental change to the adaptive variables (funds and flows) is possible when fine tuning is occurring vis-a-vis the external environment. Obsolescence of a technology occurs when it can no longer maintain its expected services (e.g. agricultural products) within the biophysical and/or social external bounds or when it cannot match internal characteristics to the external environment as well as a competing technology can.

Some notes on the role of research are appropriate here even though this material will be discussed further in later chapters. Research in agriculture has often focused on and has had its most spectacular success in pushing back the

biophysical boundaries through the addition of new factors, new practices, and genetic manipulation. On the social side, particularly in recent years, work of an essentially incremental character has been undertaken to keep the agricultural technologies within the social bounds. Work on using incrementally less pesticides or water in agricultural technology is prevalent. Work on radical adjustment (e.g. organic farming) is far less common and this is closely related to the institutional environment for research which is discussed in the next chapter.

## Summary

The objective of this chapter has been to briefly describe the reference point neoclassical concept of technology and technical change, to discuss the relevant agricultural economics literature on induced innovation, and finally to develop a systems framework for analyzing the impact of research activities on technical change. The evolution of these concepts of technical change is summarized by Saviotti:

> It is worth noting here that technological change has passed from being completely exogenous in the traditional economic position, to being completely endogenous in the models which emphasize the primacy of demand-pull, to a position which might be described as endogenous subject to constraints which might be, partly at least, internal to particular technologies. (1986, p.779)

There is a sharp contrast between the neoclassical concept of exogenous technical change and the evolutionary concept

including the intricacy and complexity of the systems framework. In general this chapter details, for our purposes, the "demand" side of technical change by conceptualizing the interactive adaptation of a technology to its environment. These are the demands placed on the internal characteristics of the technology by the external social and biophysical environment.

Research of this kind must be very clear in specifying a definite perspective on the complex systematic interactions. In our model, we view the process from deJanvry's social structure element of the innovation producing institutions. This allows a narrowing of focus to a manageable area while at the same time continuing to work systematically. The supply side of technical change, involving the specific and possible role of public agricultural research, is discussed in the next chapter.

The ideas that there are internal rigidities to technology and that the external environment of a technology is constantly in flux are both intuitively plausible and seemingly critical to research planning. In wanting to control the negative effects (e.g. ecological damage) of a technology we are left with the options of adjustment of the internal characteristics through research or the modulation of the external environment through socioeconomic policy or both. From empirical studies we know that much of technical change is incremental following a major innovation. This suggests that research may be incrementally oriented but could be

socially directed at new technologies or technological paradigms if desired. There are serious policy implications if research, for institutional and organizational reasons, is consistently confined to the provision of incremental technical change and to following the accepted "technological paradigm". If radical environmental changes are occurring causing stress on the technology, incremental change will be ineffective and a waste of resources.

# CHAPTER 3

# PUBLIC AGRICULTURAL RESEARCH

## Introduction

The focus of the present research is the role of the public agricultural research system in the evolution of agricultural technology in ecologically sensitive regions. This chapter discusses the supply of agricultural technology and technical change from the perspective of the innovation producing institutions in deJanvry's model. If the characterization of technology and its environment in the preceding chapter is correct, it indicates that the public agricultural research system faces a very complex situation which includes both social and biophysical change agents. That characterization suggests that the research system has a much more limited range of potential influence on the evolution of technology than is perhaps commonly supposed. It is only when a given research organization supplies technical change which improves the match between the internal characteristics of the technology and the external social and biophysical environment (i.e. increases "techno-economic performance") that such a change is eligible for adoption and sustained use.

A research system, however, can circumvent complexity by concentrating on simple criteria (e.g. land productivity enhancement) and by meeting the needs of a limited constituency. Our contention is that much of the criticism directed at the public agricultural research establishment in the U.S. stems from the simple criteria approach to technical change. The long term "cost" of non-systematic research planning is criticism and potential loss of public support. By extending the concept of scientific and technological paradigms we can also think of institutional paradigms which set the parameters on the products an agricultural research system expects itself to provide the public. Rigidities in institutional behavior relative to changes in the external social environment may be created over time. Historically in the United States, a clear association has existed between the research institution's scientific goals (e.g. land productivity enhancement) and the larger social system needs for cheap food. Changes in the social and biophysical system, including those arising from the pursuit of the institutional goal itself, can induce new internal goals or can lead to the demise of the institution or organization itself.

This chapter provides a basic background and review of some of the traditional work found in the literature and then develops some new concepts which are extensions of the material in Chapter 2. The first part of the chapter includes sections on the history of the public research system, the rationale for public support of the research system, and a

review of the "new agenda" for research which springs from criticism of the system. The second part provides a conceptualization of a research and education center and its interactions with its external environment. This conceptualization will be used to focus attention on certain problems and aspects of the southwest Florida case study situation. Relatively greater emphasis is given to concerns of a newly expanding organization, such as initial linkage with client groups.

Before proceeding further, an important definitional issue must be raised. There has been a good deal of debate about the exact definition of "institution" and how it differs from an organization. Ruttan notes:

> An institution is usually defined as the set of behavioral rules that govern a particular pattern of action and relationships. An organization is generally seen as a decision making unit - a family, a firm, a bureau - that exercises control of resources. For our purposes this is a distinction without difference. What one organization - a household or firm, for example - accepts as an externally given behavioral rule is the product of tradition or decision by another organization, such as organized labor, a nation's court system, or a religion. (1978, p.329)

In this study it is necessary to differentiate artificially between institution and organization even though the difference is basically one of scale not nature. Agricultural research and education institutions include the U.S.D.A., the Cooperative Research Service, the Cooperative Extension Service, and the Institute of Food and Agricultural Sciences. The applied research organization, which here is the

Southwest Florida Research and Education Center, is part of these institutions but for center planning purposes the institutions are an important component of the organization's external environment. Ruttan also presents a useful definition of institutional innovation as a change "(1) in the behavior of a particular organization, (2) in the relationship between such an organization and its environment, or (3) in the rules that govern behavior and relationships in an organization's environment" (1978, p.329). Institutional innovation is a central concept to this study.

## Historical Background

This study professes allegiance to the evolutionary mode of thinking. That makes it necessary to understand some of the historical circumstances surrounding the evolution of the institutions under consideration. Agricultural research institutions in the U.S. have taken certain historical directions that have helped determine the kinds of technology which have been developed and promoted. While the historical facts of when an act was passed by Congress or what it said are incontrovertible, there is also an element of individual interpretation of events and motivations. There has been no attempt made to provide a comprehensive review of a wide range of interpretations of the early development of the research system. The historians cited below are some of those who have attempted to explain the current criticism of

the agricultural research system by looking to its historical background.

Public agricultural research institutions were formally created in the unique historical context of the United States during the late 1800s and early 1900s through a series of Congressional acts including the Morrill Act (1862), the Hatch Act (1887), and the Smith-Lever Act (1914). This system included the formation of the U.S.D.A., the Land Grant colleges, and the agricultural experiment stations: the latter of which in Florida have become agricultural research and education centers. In Florida, these centers also include faculty from and program linkages to the academic departments on the main university campus. Nationally, these agricultural support institutions were apparently not created because of a demand from the farmers but developed in response to the value that policy makers placed on the role of agriculture in a strong American economy. Kirkendall notes that there was a fundamental change away from Jeffersonian agrarianism which dominated prior to the late 1800s and toward an industrial emphasis, at least among prominent policy makers. Kirkendall writes:

> The Morrill Act was influenced by a vision of America that differed significantly from Jefferson's. The act's vision was linked with the vision of the industrializers. In fact, Morrill worked for tariff protection for American manufacturers as well as land grants for colleges. (1987, p.46)

Danbom, in a related vein, notes that the interest in a productive agricultural sector arose as in the context of a wider strategy for a strong and competitive American economy:

> The fact is that farmers were not strongly interested in these measures, nor were agriculturalists uppermost in the minds of the policy makers. . . . They {policy makers} were concerned about the future of the nation and its economic strength in the face of static productivity, declining fertility, and unprecedented challenges to agriculture in the nation's last reserve of virgin lands. They spoke of doing something for the farmer, but their main goal was a productive agriculture that would strengthen the nation. (1986, p.110)

Early in the development of the public research system much of the proposed technical change "encouraged farmers to change their ways so as to become more efficient and productive . . . but many farmers resisted the advice" (Kirkendall 1987, p.47). Agricultural science or "book farming" was contemptuously regarded by many traditional or technologically conservative farmers.

Both Danbom and C. Rosenberg have proposed similar theses on the evolution of the public research institutions. They see current criticism of the system, particularly that related to the system's focus on the needs of large commercial agriculture, as having root in the early institutional development and relationships among actors. Contrary to the apolitical aspirations of many scientists the development of the entire public research system was subject to the politics of the time. Danbom states:

> All of the components of the system were intimately involved in politics from the beginning on, though

> many scientists were unwilling or unable to recognize that reality. Legislative and Congressional appropriations, issues of governance, site selection, and even the programs of work were political questions, and the perceptive pioneers in the research establishment recognized that the health and even the survival of their institutions was tied to their political acumen and the political alliances they made. (1986, p.115)

As with any political organization support had to be encouraged and maintained so as to ensure continuing appropriations. The natural clientele for the research institutions was the more entrepreneurial farmers who were interested in the new technologies and increased production. Danbom notes:

> As might be expected, the research institutions were most likely to attract support from and make alliances with groups which already shared their outlook and sympathized with their work. Businessmen, bankers, and highly specialized, market-oriented farmers were all likely to agree that the problems of agriculture were mainly problems of production, and that these could be solved within agriculture if farmers became more professional. (Ibid., p.116)

The relationship between entrepreneurial farmers and the research establishment has tended to carry over to the present day.

Neither Danbom nor C. Rosenberg attribute any sinister motives to those in the research establishment. C. Rosenberg, in specific reference to the agricultural experiment stations, writes:

> Stated crudely, experiment station scientists and administrators never considered the possibility that insofar as their work proved successful it might help enrich the rich, impoverishing and ultimately forcing many worthy if less entrepreneurial farmers from the land. (1977, p.402)

The goal of improved productivity provided the research establishment with a perfectly legitimate "scientific" objective and also provided a basis for maintaining a necessary and powerful client group that would lobby for continued support. In reference to the early agricultural scientists C. Rosenberg states that "their ideological stance rested on an unquestioned faith in a transcendent virtue of productivity; to increase the productivity of the soil - to make two blades of grass flourish where one had before - was to act in an unambiguously moral fashion" (Ibid., p.403).

It is clear that some of this historical character of the system has carried through to the present day. It is worth noting that various other agricultural observers paint a much more positive picture of the system's genesis than Danbom and C. Rosenberg do. They typically accent the benefits to the "public" in the form of an abundant food supply as opposed to highlighting the association with powerful client groups and the displacement of many family farmers.

## The Rationale for Public Support

Both theoretical support and empirical evidence of the societal benefits resulting from the public agricultural research system figure prominently in the agricultural economics literature. Approximately half of the productivity growth in the agricultural sector has been estimated to be attributable to public research (Ruttan 1982). According to

conventional economics, the public is posited to invest in agricultural research in order to ultimately produce food at less cost. Some benefits accrue to producers and others to consumers depending on commodity demand parameters. The logic of this follows directly from the neoclassical measurement of technical change where technical change is characterized as reducing production costs.

The argument for public support to research comes in two parts: theoretical and empirical. First, economists point to the nature of research itself as being an enterprise which is not well suited to the market economy. The incentive structure for certain types of research (e.g. research on cultural practices) breaks down in the market economy where results must be incorporated into a product or patented for a private firm to recover its research investment. The second part of the argument consists of the presentation of numerous empirical studies which show, almost without exception, very high returns to the public's investment in agricultural research through the U.S.D.A., Land Grant colleges, and agricultural experiment stations. Generally, then, the conventional position is that research is performed that would not normally be undertaken in a pure market situation, and the results have uniformly proven worth the investment to the public. This apparently solid package of theoretical rationale and empirical support merits brief review.

There are strong theoretical reasons that some types of important agricultural research would not be conducted by the

private sector. From a theoretical viewpoint, information or technology can possess certain attributes which defeat the optimal price allocation mechanism in the conventional neo-classical model. These attributes are indivisibility, inappropriability, and uncertainty. In the central theoretical piece on this matter Arrow states:

> To sum up, we expect a free enterprise economy to under-invest in invention and research (as compared with the ideal) because it is risky, because the product can be appropriated only to a limited extent, and because of increasing returns in use. Further, to the extent that a firm succeeds in engrossing the economic value of its inventive activity, there will be an under-utilization of that information as compared with the ideal allocation. (1971, p.175)

Arrow goes on to note that information should optimally be distributed at its marginal cost of distribution which is typically negligible. However, the innovator should be paid according to the social benefits derived from the information. There is a divergence then between the optimal distribution requirements and the optimum compensation requirements. This results in the conclusion that: "for optimal allocation to invention it would be necessary for the government or some other agency not governed by the profit-loss criteria to finance research and invention" (1971, p.179). It is precisely this social opportunity to invest which provides, at the macro level, a theoretical rationalization for the public funding of the institutions which we are studying.

Building on the general theoretical foundation, many economists and agricultural economists have estimated the returns to public investment in agricultural research. This body of work usually falls under the heading of the "public underinvestment in agricultural research" hypothesis. This hypothesis states that significant income streams are foregone by not increasing funding to public agricultural research. Pioneers in the empirical estimation work have developed some of the basic analytical techniques. The two basic approaches which dominate the literature are the estimation of producer and consumer surplus resulting from price decreases and the estimation of the research coefficient in the aggregate agricultural production function.

While the notion of high returns (30-60% per year) to agricultural research investment is widely accepted in the conventional literature (Ruttan 1982, p.242), controversy does exist on the specific estimation procedures. The intradisciplinary technical controversies concerning estimation are not of primary concern to us. Without going into the extensive literature on this topic it is perhaps worth noting that numerous assumptions are needed to obtain numerical results. There is no standard estimation procedure for determining returns to agricultural research investments even for a given type of measurement. For example, regarding the behavior of the supply curve in

consumer-producer surplus measurement, Norton and Davis write:

> Griliches assumed a parallel shift (horizontal or vertical); Peterson a proportional shift, Hertford and Schmitz a parallel shift, Akino and Hayami a pivotal shift, and Lindner and Jarrett and Rose four shifts. The nature of the shift assumed is very important. (1981, p.689)

It should be noted, however, that despite divergent methods and different commodity or geographic foci the majority of historical numerical estimates do demonstrate surprising uniformity falling generally in the 30-60% per annum range.

A number of questions and criticisms emerge from the conventional rationalization for public involvement in agricultural research. First, the theoretical justification of publicly funded research, which centers on the presence of market failure, requires that the institutions produce "public goods" (i.e. goods that are non-rival in consumption and nonexcludable). Research, in the conventional view, should only be conducted in those areas where private incentives do not exist and can not be developed through changes in the incentive structure (e.g. changes in patent laws). Research on mechanical technology, for example, would generally fall outside the public domain.

There are two concerns with this perspective. First, a major role of the public research system is to provide alternatives to privately developed technology. Harvey notes that one of the major reasons for publicly funded research is "to control or direct R and D effort in the public interest

as opposed to the private interest, where there is a conflict between the two" (1988, p.89). Second, there does not appear to be any supporting evidence in the literature demonstrating that public research facilities have carefully avoided research in areas where private research enterprises could operate or could be made to operate.

Another question relates to the use of the empirical return estimates relative to the issue of underinvestment in public research. At the macro level apparently no attention has been given to how federal and state budget makers could use these estimates to allocate funds between agricultural research, prisons, roads and so on. Numerical return estimates on some forms of public investment (e.g. prisons) are practically impossible. Agricultural research may or may not have a high rate of return relative to the private sector but that comparison is not the relevant one. Alternative public investments need to be compared. In addition, some authors stress that historical estimates of high rates of return do not necessarily imply that future investment will yield those rates (Pasour and Johnson 1982).

Further contradicting the underinvestment hypothesis is some evidence that the rates of return, even as conventionally measured, are now declining to more modest levels (Harvey 1988). This is to be expected. The research system has laid claim to a role in a long term decline in food prices which is now, in effect, bottoming out. Finally, there appears to be enough technical criticism of the

accuracy of the estimation processes to warrant some skepticism on the part of policy makers. Even a cursory reading of the literature indicates that many arbitrary assumptions (e.g. the lag structure in the production function) and a variety of non-standard aggregation schemes and indexing have to be used.

Much of the conventional literature on the economics of agricultural research involves technical measurement controversies. Technically oriented economists can find many puzzles to solve amidst this material. However, it is one thing to be concerned with the accuracy of a given measurement. It is quite different to question the nature of the variable being measured and to ask to what extent that variable represents the public benefit from public agricultural research. Equating producer and consumer surplus with public benefit is a value proposition, embedded in the neoclassical theoretical model. There is no doubt that the public does benefit from cheaper food all else being equal. But there are a variety of effects (e.g. ecological) of agricultural research, and the technology it produces, that go beyond cheaper food prices.

The particular form of economic measurement (i.e. consumer/producer surplus) conventionally used is, however, a "two edged sword." In a situation of rising prices it will show negative returns to agricultural research. For reasons unrelated to agricultural research, such as droughts and freezes, prices can rise reducing consumer surplus and

driving some producers out of business. In the state of Florida for example, because of freezes in this decade, returns to citrus research if measured in conventional terms have possibly been negative. Research on sustainable agriculture, to the extent that it leads to higher production costs, also registers negatively in terms of the conventional benefits of agricultural research. Careful reconsideration of the use of market oriented measures are in order. A dollar input to the research system is inaccurately measured solely by the effect it has on cost reduction. Consideration of accompanying equity and ecological costs and benefits is warranted.

Current real world problems of maintaining public support for agricultural research are not likely to be resolved by more sophisticated and accurate statistical estimates showing high economic rates of return. Criticism of the system has not revolved around the need for lower food prices but has instead focused on adverse environmental and distributional consequences of some of the technology produced with public funds. It is important that the research system demonstrate that it is not displacing private enterprise or unduly benefiting special interests. Effective work in pursuit of the "public interest" as broadly conceived is required. The so-called "new agenda" for agricultural research represents a more inclusive set of social objectives for publicly funded institutions. It calls into question the preeminent status of the historic goal of increased land and

labor productivity which has united researchers and certain segments of the farm community.

## The New Agenda for Agricultural Research

The public agricultural research system is a political creation which depends on legislative appropriations for maintenance and growth. Public criticism is a threat to research institutions and should not be underestimated. The scope and intensity of support or criticism at any point in time are critical to the survival and reorientation of those institutions. Optional public institutions, such as the public agricultural research system, are more vulnerable in terms of survival than necessary institutions such as the police. At some level, public demand for change obliges administrators and faculty to consider directions for research which had not previously been within the institution's purview.

We are currently in an extended period of criticism of the research system dating back to the publication of Rachel Carson's Silent Spring in 1962. The criticism usually has been at a low level but has had some sharp peaks. Key publications, such as Silent Spring, the Hightower Report (1973), and the Pound Committee Report (1972) have provided rallying points for environmentalists, advocates for the rural poor, and critics of the system's internal structure and incentives. An extensive survey of over 1400 public

agricultural researchers' attitudes indicates that criticism is not with-out foundation:

> Scientists overwhelmingly emphasize the creation of disciplinary knowledge and the increase of agricultural productivity as the most important goals for agricultural research. Many other goals, such as human nutrition, improving rural levels of living, and improving communities, tend to be relegated to one or two disciplines. . . . There is a surprising lack of concern for contemporary agricultural issues among agricultural scientists, particularly among basic scientists and those with a basic science orientation. (Busch and Lacy 1983, p.233)

There has, however, not been a widespread public outcry which would induce radical change or the creation of new institutions.

Silent Spring, the Hightower Report, and the Pound Committee Report each may be characterized as primarily representing a major historic strain of criticism of the public research system. A neglect of the environment and consumer health, an exclusive concern with the well being of large farmers and agribusiness, and scientific incompetence and disregard for basic science are, respectively, the charges leveled. Reformers have rallied around the first two of those criticisms to propose what Paarlberg (1980) first called a "new agenda" for agricultural research. The "new agenda" includes farm labor issues, rural development concerns, a reevaluation of commodity programs, and work on environmental and consumer health problems. On this point Batie notes:

> The public's contemporary agenda does not include an abundant domestic food supply; it addresses

> instead the social problems that have partially and indirectly been generated by past Land Grant successes - environmental pollution, bankrupt farmers, or poor human nutrition. Colleges of agriculture need to demonstrate efficacy in addressing these issues. (Batie 1988, p.2)

The new agenda issues have been given at least rhetorical attention in many of the official publications of the various components of the research system.

The items on the "new agenda" aim to address a larger constituency. Aside from a sense of duty to "the taxpayers," there is a pragmatic realization that the system's client support group, though powerful, is continuing to dwindle in size. Not only is the traditional client group small numerically, it has also begun to conduct its own research and establish links with private supply firms in the productivity enhancement area which is the traditional forte of the public system. In this regard Bonnen states:

> With the ability to patent plant material and biotech processes and with concentration has come a more rapid growth of private agricultural R&D. The private sector is now taking over many areas of applied research that have been the public responsibility. (1987, p.125)

The public research system faces a strategic problem of justifying itself to a taxpaying, and increasingly tax conscious, public. No logic exists for a special public institution whose work can be handled in the private sector.

The internal institutional issues are more complex than the external criticism. Contrary to the Pound Report charge of lack of attention to basic science, other more recent

criticism (e.g. Schuh) notes an overemphasis on discipline-oriented basic research. Schuh writes:

> Today the criteria for promotion is publishing in scholarly journals. In turn people are self- and peer-oriented. They do not feel a responsibility to the institutional mission of solving society's problems. They do research to advance knowledge, publish for peers, and earn consultancies. Generating and applying knowledge to solve today's social and economic problems are not given sufficient priority. (1986, p.6)

This sort of apparent contradiction may indicate a fundamental dissociation between basic or disciplinary research and applied or problem solving research. It may also indicate that disciplinary paradigms are established and adhered to in such a way that a disciplinary breakthrough has little to do, over any reasonable time period, with applied problem solving. Competence or incompetence at the basic or disciplinary end of the research spectrum may have limited relevance to the real world. Moreover, the general notion, developed by Schuh, Bonnen, Batie and others, that researchers are not addressing applied problems raises additional doubts about the high annual rates of return claimed for the public agricultural research system.

These institutional and organizational issues may be productively analyzed in a fashion similar to that employed in Chapter 2 relating to technology. Divisions between the internal and external conditions are artificial but they do allow us to differentiate between problems arising from the technological output of the research system and those relating to internal institutional characteristics. Changes in

the internal structure and incentives (e.g. greater rewards for multi-disciplinary work), as many point out, would naturally change the kind of technological output provided. External pressures, particularly those from the legislative level, can also induce changes in the internal structure, its management, and methodology. This is similar to our development of the notion of technological evolution.

There can, however, be tremendous institutional resistance to change. The internal structure of an institution may not respond to criticism or change in the external environment just as a technology need not automatically respond to a change in relative prices. Some of the historic strengths of the system may become liabilities if they inhibit growth and change. Institutional evolution is hampered and may only occur during times of intense external pressure. Institutions become insulated from changes and needs in the external social environment. This is certainly the implication behind the "new agenda" for agricultural research.

## Priority Setting for Agricultural Research

An individual research and education center could have the potential to develop its own goal oriented research program. The possibility of such a program depends fundamentally on coordinating the activities of individual faculty from diverse disciplines. The faculty in the centers, however, encounter a complex array of influences and demands

that are not likely to be fully harmonious. At the center, each faculty member interacts with the center administrators, fellow center faculty, producer groups, and other regional interest groups. State level influences include academic deans, department heads, disciplinary colleagues, and state funding sources. Finally, at the national level are the disciplinary associations, various research funding organizations, and the U.S.D.A.

The presence of these diverse forces, as well as personal preferences, restricts the potential influence that an administrator might exercise in directing research and technological development through the problem choice process. In the nationwide Busch and Lacy researcher survey, "priorities of the research organization" ranked eleventh out of the twenty criteria listed in influencing problem selection (1983, p.45). Personal enjoyment was the most highly ranked. They summarize the results of their findings on problem choice as follows:

> Despite the seemingly straightforward character of decisions about problem choice in agricultural research, closer examination reveals an extraordinarily complex process. In addition to scientific or paradigmatic criteria for problem choice, administrative directives, political commitments, and personal avocations are among the other factors that play a role. These criteria emerge from a complex process of negotiations and often operate together to shape problem choice. (1983, p.230)

This complexity is a partial function of current institutional arrangements and can be changed by external pressure, particularly of a legislative nature. It can be reduced by

internal incentives which more clearly help define the range of possible problems for a given researcher.

There are, in addition, powerful social values at work which tend to favor academic freedom and independence for the individual scientist. Abuses of this freedom have undoubtedly occurred as evidenced when researchers informally cite "whatever will produce lots of publications," "whatever they can get funding for," or "what's easy" as their guiding factors in problem choice (Busch and Lacy 1983, p.1). The discretion of an administrator in terms of defining and promoting a specific research agenda is then limited. The administrator is only one of a group of influential actors who hold sway over individual researchers. The scope for priority setting is limited by researcher autonomy and a hierarchical system which gives administrators little authority over problem choice. Administrators themselves also have many, and often conflicting, pressures brought to bear on them. They must deal with national and state institutions and interest groups, their own job security, and a growing bureaucracy.

Relatively little work has focused on the priority setting processes at the level of the individual U.S. research and education center. One of the most fundamental problems in priority setting is the normative judgments that must be made. Paulsen and Kaldor discuss the complexity of the situation:

> In the context of an experiment station, whose goals are relevant to the evaluation of research? Is it the personal goals of the scientist or those of his professional society? Should one use the goals perceived by department heads or those articulated by station administrators? Who makes up the station's public? And who should articulate this public's goals? Since there are multiple goals there is a weighting problem. What is the relative importance of each of these goals to the station's public? Who should specify the number of units of one goal that will substitute for one unit of another goal? (1968, p. 1151)

In the face of bewildering complexity the system has, over the years, tended to focus on the goal of productivity increase and particularly on yield per land unit and in earlier times yield per labor unit. As noted above, research leading to an increase in a simple productivity measure (e.g. yield per acre) provides a clear scientific objective and a rallying point for researchers from diverse disciplines. Productivity increasing technology often benefits the general public (i.e. as consumer surplus) as well as some segments of the producer group, especially the leaders in new technology adoption.

The public, which is the source of the institutional financing, is the ultimate recourse in terms of goal setting. It is difficult, however, to define the public interest in a meaningful way since there are many different interest groups and many possible tradeoffs between social goals. Clearly, it would be in the public interest to have an ecologically benign agricultural production system, which provides well paid employment for interested workers, while at the same time producing abundant and diverse high quality food at a

price all can afford. Historically, the simultaneous attainment of those goals has not been possible. An improvement in one area (such as land productivity) has meant a loss in another area (distributional equity). A well-known article by Schmitz and Seckler (1970) showed a return of 929% on research which developed hard tomatoes for the purposes of mechanical harvesting. The accompanying effect of successful mechanization was a displacement of 19 million man hours of labor per year.

In the literature a number of different approaches to research priority identification have been taken. Paulsen and Kaldor begin with a public investment perspective:

> The output of research investment is new knowledge. New knowledge is wanted by taxpayers, not for its own sake, but for the contribution it is expected to make to other ends. The researcher, of course, may well be as much motivated by intellectual curiosity as by social return. The output of research is valued as an investment of society because goal attainment is enhanced by new knowledge. (1968, p. 1151)

In their empirical work Paulsen and Kaldor identified three broad social goals: growth, equity, and security; and then employed expert panels to develop long range research plans for the Iowa state system. This methodology represents what is called the scoring model approach which, along with cost benefit studies, simulation models, and mathematical programming, are the primary approaches. Scoring models rely on subjective expert opinions of scientists as to the probabilities of research success in specified research lines. Cost benefit analysis is similar to traditional cost benefit

analysis except that it depends on predictions as to potential cost reductions and yield increases. Simulation models are sets of related equations which are very flexible and can include a wide variety of constructs. Finally, mathematical programming can be used to identify optimal mixes of resource allocation in regard to some objective function. The use of these techniques requires some clear specification of the goals to be attained. They also may require that a single variable be maximized as in the case of mathematical programming. From a practical point of view, these models also require a large amount of data and staff time. They all represent extensive research projects in their own right and require periodic updating as conditions change.

Before the operational mechanics begin, the first step in these techniques is the specification of social goals and tradeoffs. There is tremendous reticence in the scientific community to engage in normative work, so appeal is usually made to "the market" or to the legislature to give the research organization apparent independence from the goal setting process. In work subsequent to the Iowa study, Kaldor (1971) "made a plea for legislative attention to the problem of formulating a rigorous and operationally useful social welfare function" (p.78). Attention to the value free signals of the market has, of course, been the basis of the induced innovation work of Ruttan. Ruttan suggests that farmers pressure research organizations to find ways to

economize on scarce factors of production. As deJanvry has pointed out, farmers are not a homogeneous group and therefore scarce factors are different, depending on the characteristics of each farm operation. The supposed value free market signals are typically distorted in the socio-economic structure.

We recall from Chapter 2 that technology itself is not very malleable and that the innovation producing institutions are only one element in the wider social system which includes the socioeconomic and politico-bureaucratic structures. The work of the innovation producing institutions is additionally circumscribed by the characteristics of the bio-physical environment. The link between applied research and public benefit has shown high economic returns, but the measurement procedures are questionable and clearly fail to account for associated social and ecological costs. Within the structure of the innovation producing institutions, the individual research and education center represents one element in the hierarchical state and national public agricultural research system. At the center level in the various states, an administrator has restricted influence over the work of the center researchers. The administrator is confronted with an array of potential research program priorities but has no objective basis to choose among them in the public interest. The barriers against the possibility of research planning at the center level, throughout the U.S. and in developing countries, are strong.

One of the results of studying institutional complexities and problems in the public agricultural research system is confrontation with the notion that a deterministic maximization procedure may be successfully employed for planning at the center level. The administrator does not typically have extensive influence over the center research agenda and it is clear that public goals are not one dimensional for agriculture. In conventional neoclassical economics, the prescription for optimal allocation within a fixed budget would be to equate net marginal benefits across different research projects. This prescription is indeed correct if we could economically quantify with certainty all of the costs and benefits of research projects. That is not likely to ever be possible. The "new agenda" for agricultural research may render completely invalid the traditional measures which exclude social and ecological costs.

There is an inevitable normative element that enters the discussion when suggesting what could or should be done. There is some suggestion that the public research system is not providing the services demanded by the broad tax paying public (Batie 1988). We have seen that because of isolation from the social environment that some individual researchers have priorities that have little to do directly with solving applied social problems (Schuh 1986). These individuals survive and often flourish in the public research system. If the public, through their representatives, has not acted to censure those who do "whatever they enjoy" or "what's easy"

then such pursuits would seem to be legitimate uses of public funds. In such an environment of organizational anarchy there can be no coordinated planning or specific center agenda.

## The Research and Education Center System

There is very limited literature which adopts a research and education center perspective. Blase and Paulsen, however, have developed a systems perspective on the interaction of the center with its social environment. This section draws heavily on their 1972 article: "The Agricultural Experiment Station: An Institutional Development Perspective" which has been widely used in the agricultural development literature. Interpretations have appeared in the work of Ruttan (1982) and in that of Evenson and Binswanger (1978). These two interpretations are also utilized below. The Blase and Paulsen work provides an understanding of the structure and function of a research center which is the basis for planning.

Blase and Paulsen conceptualize the research and education center system as employing stock and flow resources to produce intermediate products which are, in turn, transformed into final outputs (Fig. 3.1). They divide the system inputs into flow and stock resources. The primary input flows are staff time, services of buildings, and the interest and cooperation of client groups. Both staff time and building

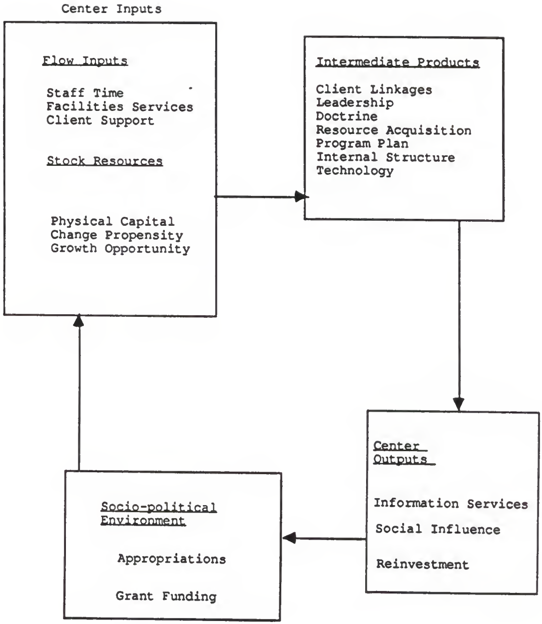


Figure 3.1. Research and Education Center System (Adapted from Blase and Paulsen, 1972).

services typically require annual budget allocations from state and federal sources. Unlike with some systems, input flows in this case may not be accumulated but must be utilized on a continuous basis.

The major types of stock resources are physical and human capital. Physical capital includes buildings, laboratories, experimental plots, and materials. Human capital is the intellectual capacity of the staff which, like physical capital, is subject to enhancement and depreciation. Human capital is not easily measured but it can be improved through training programs and refresher courses.

The other stock resources, called growth stimulators by Blase and Paulsen, are change propensity and opportunity for growth. Change propensity is basically the staff's willingness to accept change in order to exploit center growth opportunities. It involves willingness to take risks. Opportunities for growth may be external or internal. External opportunities are present if the possibility of contributing to the achievement of widely and strongly held social goals exists. External opportunities may or may not be taken advantage of by a center. Growth may be constrained internally if services are offered only in narrow areas of limited social value. This would be the case if a center research agenda was focused on a crop which is declining in importance in a given region.

Seven intermediate products, viz. linkages, leadership, resource acquisition, doctrine, program, internal structure, and technology, are used in the Blase and Paulsen model to produce the outputs of a research and education center system. The intermediate products have limited direct value to society but they are the "system's engine whose functioning determines the efficiency with which the system makes use of its resources" (Evenson and Binswanger 1978, p.206). We note each below placing emphasis on those items that are of most relevance to the case study of a newly developing center in southwest Florida. It is clear that items 1-4 are most important in setting the goal orientation of the center while items 5-7 are related to management to achieve established goals.

(1) Linkages are relationships with external institutions, groups, and individuals. Of primary importance is the selection of client groups with which linkage relationships are built. It is through these interactions that the center obtains signals from society enabling it to engage in high priority research. Commenting on the linkage component of the Blase and Paulsen model, Evenson and Binswanger note:

> The linkages carry messages in both directions. It is through these linkages that a research institution influences technical and institutional change within its field of endeavor and is in turn influenced by changes in related science and technology and in society at large. (Ibid., p.207)

In the Blase and Paulsen model, the identification of client groups is a critical strategic decision. Blase and Paulsen

note that "research stations must carefully decide which of the old linkages they should continue and what new linkages should be built" (1972, p.14). They also state that "at a time of changing research needs and stagnant or falling budgets, research stations would be well advised to study carefully their past choice of linkages"(Ibid., p. 14). Maintaining relationships with outside groups without becoming a captive or an adversary of them may be a very difficult task (Ruttan 1982).

(2) Leadership is responsible to transmit social and economic signals to the center faculty, to interact with clients, and to organize the institution's intermediate products in such a way to ensure the best possible mix of final outputs for society. It is an extremely important intermediate activity. Ruttan states:

> The idea that all a research director needs to do is to hire good people and let them "do their own thing" has only minimal relevance at a time when the solution to many significant technical and social problems requires concerted research effort. Leadership must be sensitive to changing social goals, and it must effectively transmit their implications to the scientific staff. (1982, p.207)

(3) Resource acquisition is a resource using activity most typically engaged in by the center administrator and is closely associated with leadership. It is effort deployed "to recruit and mobilize professional personnel, obtain legislative appropriations, negotiate grants and contracts, and build and maintain information pools and physical facilities" (Blase and Paulsen 1972, p.16). Evenson and Binswanger note

that "leadership also involves resource acquisition. Leaders must be able to visualize and describe to others how the experi-ment station or research laboratory can contribute to the solution of current problems" (1978, p.207).

(4) The intermediate product of doctrine "provides the basic character of an institution and helps to clarify and express its philosophical framework, including identification and weighing of basic institutional goals, and delimit the range of means by which the research station will operate" (Blase and Paulsen, p.15). Blase and Paulsen suggest that there are two competing doctrines seeking to replace the historic doctrine of service for increasing agricultural output. The science oriented doctrine is most concerned with professional publication and prestige while the social service doctrine is more directed at attainment of social goals. Evenson and Binswanger state:

> The United States federal-state agricultural research system has been under increasing pressure to give greater emphasis, in establishing its research priorities, to environmental spillover effects of technical change in agriculture, to problems of human capital formation, and to institutional dimensions of community development. Although the system's doctrine as stated has begun to reflect these altered emphases, in actual practice its traditional orientation toward production remains strong. (1978, p.208)

(5) Program is the tangible expression of doctrine. It is the actual allocation of resources to problem areas. It reflects the nature of the desired mix and type of organizational output.

(6) The internal structure is manifest in the organizational chart and all of the informal relationships which affect the production of information. It is the most visible reflection of both program and doctrine.

(7) Finally, technology is the production process of converting the system inputs to intermediate and final outputs. (This use of the term technology is more specialized than in the other parts of this study.)

The three final outputs of the research center system are information, investment in future capacity, and social influence. The information output is critical:

> In the long run, only information outputs of research institutions can justify their use of public resources. This information output must make enough net positive change that leaders widely recognize the greater achievement of social objectives made possible as a result. (Blase and Paulsen 1972, p.12)

The substance of the information output is embodied in specific technologies (e.g. high yielding varieties) or is in the form of papers, reports, questions answered, and so on. The information output "contributes to society by providing new understanding that widens the range of choice, increases the options, or reduces resource constraints" (Ibid., p.12). The second output, investment in future capacity, involves the enhancement of the center's resources of physical and human capital. This output includes the development of new skills by staff, restocking libraries and laboratories, and program review and planning. Finally, an institution's influence output relates to the external social and political

environment. It is a resource using output for which time invested is especially important. Its purpose is defined as follows:

> By influence, the institution hopes to (a) insure its own survival and increase its chance to obtain support and (b) develop a greater appreciation for its current services among its beneficiaries or, in the case of experiment stations, promote faster and more eager acceptance among users for its information outputs. (Ibid., p.13)

Blase and Paulsen posit a number of loops in the system, the most important brings the funding resources from society into the center, based on the value of the center's output to the public.

The fundamental objective is that the organization grow in terms of stock and flow inputs by broadening and intensifying the base of client support. The key feedback loop links the center's outputs (i.e. services, influence, and institutional reinvestment) with the new inputs to the system. Conveniently, as Ruttan (1982) notes, we can envision the socioeconomic and the political-bureaucratic structures from the deJanvry model as being on that key feedback loop and determining what the public investment in the form of budget will be (Fig. 3.1).

The Blase and Paulsen conceptualization provides a somewhat different perspective than the Busch and Lacy researcher survey would suggest. The system conceptualization requires that the research center be attributed a unified organizational purpose, which in the Blase and Paulsen model, is to maintain itself and grow. Blase and Paulsen note that "the

goal of a research station is progress, and to achieve this goal it must generate information. All the station's components relate and contribute to the station's mission of progress for society" (1972, p.11). This abstracts from some of the fundamental problems Busch and Lacy presented, such as the existence of faculty with goals unrelated to the priorities of the research organization. Under the doctrine category of intermediate products Blase and Paulsen do not discuss whether the science doctrine geared to publication and professional prestige is inconsistent with generating information directed at the achievement of social objectives. Schuh, and other critics noted earlier, do suggest an inconsistency between a dominant science doctrine and the applied mission of the public agricultural research system.

Public criticism of research institutions or of a specific research organization limits ability to obtain sufficient funds for growth. If support for the larger institution or the specific organization is not forthcoming at maintenance or growth levels, that signals a need to use internal resources differently to change the nature of the output. In reviewing the Blase and Paulsen model, it is clear that the central element is the linkage relationship with client groups. The establishment of client group linkages is central to determining the type and nature of the system outputs. Those outputs, particularly the technologies developed, create the impetus for public support including the potential for the growth of the organization.

The linkage establishment process needs to be dynamic. Relationships with new groups can be explored over time to determine what support is generated for the organization. Blase and Paulsen note that "we cannot afford to ignore the information needs of well represented potential beneficiaries, even though investigations required would be non-traditional" (Ibid., p.17). In the ideal situation, the support of a basic historic client group could be built into the support of a coalition of groups. A coalition building strategy may, however, encounter serious difficulty. First, the traditional clientele will not wish to lose influence through the addition of new clients. Second, the research center may have become locked into certain routines and methods after a period of dealing with a given clientele. The faculty may lack the change propensity needed to incorporate new projects into the research agenda. In terms of our case study in southwest Florida, there is a unique opportunity to explore relationships with new client groups and to develop change propensity among the center's staff from the inception of the organization. As an institution or organization matures routines become fixed and change less likely.

Finally, since in the southwest Florida case study the research center is newly expanded with only 3 of the planned 14 faculty members currently on staff, it is useful to take note of the role of the research center director. This does not imply that individual faculty do not have their own

duties and responsibilities to clients. The center director does, however, occupy a key position that is often identified as a "policy maker" in the social sciences. This individual is a public official. Control over public funds is exercised as part of the job. The director also has some, though not full, authority over the hiring of center researchers. It should be noted that the center director is also a scientist but typically has limited time to work on research projects due to the administrative demands of the position.

Two perspectives on the potential for a unified goal-oriented research agenda at the center level were presented above. The first showed little serious potential because of strong faculty affiliations and goals exogenous to the research center. In order to discuss a center agenda or research planning it is necessary to make an assumption that some influence over the faculty, after initial hiring, is exercised by the center director. The systems perspective of Blase and Paulsen includes an important role for the center director both as a leader and a resource manager. All of the intermediate products in their model are, to varying degrees, under the influence of the director. The director is involved in the critical areas of establishing linkages with client groups, framing doctrine, working out resource use plans, and building internal organizational structure. Resource acquisition is another important task that requires leadership and diplomacy.

The actual position description for the director of the SWFREC is consistent with the conceptualization provided in the Blase and Paulsen model. Among other things the position description states:

> Duties include overall leadership and coordination of programmatic functions and development of facilities necessary for successful implementation of research, extension and teaching programs directed at solving problems confronting agricultural industries in southwest Florida. Incumbent must work closely with agricultural producers, county extension faculty, faculty in other IFAS units, other agencies, agribusiness leaders, public officials, the media, and the general public. . . . The incumbent must actively pursue the acquisition of donations for program support from potential donors, and extramural funds from granting agencies and private organizations. (Arnold 1987)

Leadership duties, establishment of linkages with groups, resource acquisition, and management responsibilities are stressed in the actual position description as they are in the Blase and Paulsen conceptual model.

## Conclusion

We noted earlier in this chapter that a number of methods for research planning (e.g. scoring models, cost-benefit, and mathematical programming) have been attempted in practice and reported in the literature. Such techniques could be used to help determine the priorities of a research center. There are three major problems. First, researchers have their own orientations which carry over from their disciplinary training. They are not likely to be greatly influenced by the results of a planning model. Second, it is

difficult to reflect joint goals, such as land productivity and environ-mental protection using those methods. The problem is complicated by the unpriced and unknown values associated with the environment. Third, these approaches represent very substantial research projects in their own right and typi-cally require a significant amount of staff time and resources to keep the models functional and up to date. Ruttan (1982) notes that a major limitation in the use of cost-benefit models is that the costs "involved in estimation, data storage and maintenance, and economic analysis can easily be underestimated by several magnitudes" (p.286). There is no example in the available literature of these methods being applied for an individual research center, probably because they do involve the diversion of too many internal resources (e.g. staff time) which could be used for information production.

It is suggested here that the Blase and Paulsen perspective regarding research planning, tempered with the realities of the Busch and Lacy survey results, would be most productive. Micro-planning techniques, such as mathematical programming, would appear impossible and probably inadvisable. It seems that the research center system is guided by a number of interrelated control decisions revolving around the intermediate products in the Blase and Paulsen model (Fig. 3.1).

Relative to the southwest Florida case study, early crucial decisions must be made about 1) the establishment of

organizational doctrine and goals, 2) the choice of client groups and development of linkages, 3) the mix of the disciplinary specialties of the faculty, and 4) the direction of resource acquisition activities. These decisions, as a whole, help determine the initial "trajectory" of the center. This trajectory may be difficult to redirect at a latter date if the need arises. The SWFREC is part of the larger state agricultural research institution (IFAS) and, because of the prevailing institutional paradigm, the center is circumscribed in its decisions. There is a limited degree of autonomy at the center level. The next chapter details some of the institutional and organizational functions and relationships of importance to an understanding of the southwest Florida situation.

# CHAPTER 4

# TECHNOLOGY AND INSTITUTIONS IN SOUTHWEST FLORIDA

## Overview

The Southwest Florida Research and Education Center is proceeding to develop its research and education program in accordance with a traditional institutional paradigm which focuses primarily on the needs of commercial production agriculture. The creation of the center and the early development of its program has been a direct function of both state legislative action and the orientation and priorities of the state public agricultural research institution (IFAS). In the preceding chapter, it has been suggested that the traditional paradigm may no longer be viable at the national and state level (e.g. Batie 1988). The major concern of this study is whether the traditional paradigm, oriented toward commercial agriculture, will be viable for long term maintenance and growth of the center in southwest Florida, given the social and biophysical conditions of that region.

In areas of the U.S., including Florida, instances of incompatibility between existing commercial agricultural production processes and natural resource protection have been documented. In the U.S., concerns have been raised about

soil erosion, declining water tables, salinization, various forms of pollution, and increasing use of pesticides due to pest resistance (Dahlberg 1986). In Florida, a number of potential incompatibilities have been acknowledged including those related both to reductions in natural stocks (e.g. wildlife habitats) and degradation of natural flows (e.g. water). A recent IFAS report states:

> The unintended consequences of agricultural chemicals are potentially an impediment to compatibility between agriculture and urban interests. Agricultural production in Florida is heavily dependent on fertilizers and pesticides but the natural environment of the State makes it difficult to control the diffusion of these chemicals to off-farm areas. Some widely reported episodes of chemical contamination of surface and groundwater, aerial drift of pesticides to people and animals in proximity to farms, and residue levels on food products, are all potential exposure pathways that have become points of conflict between agriculture and off-farm interests. (1986, p.247)

In Florida in 1982, environmental officials discovered that drinking water wells had been contaminated by the pesticide Temik, and in 1983 more wells were discovered to contain the pesticide EDB (Fernald 1984, p.255). When a specific substance, used only in agriculture, appears in the water supply it provides clear evidence of an adverse impact of agricultural technology. Often impacts are not so clear or readily documented.

A good degree of attention in Florida has focused on the effects of agricultural production on Lake Okeechobee, the largest lake in the state and part of an extensive natural system which also includes the Kissimmee River and the

Everglades. A Florida Department of Environmental Regulation report states:

> Over the past decade, phosphorous in Lake Okeechobee has doubled, despite all attempts to reduce it. The lake appears to be losing its ability to assimilate phosphorous. If the trend continues, it could become overenriched - a major environmental loss for Florida. Significant amounts of phosphorous come from dairy farms and improved beef pasture in the Taylor Creek-Nubbin Slough Basin and and the basins of the Lower Kissimmee River north of the lake, and from sugar cane, vegetable farms, and pastures in the Everglades Agricultural Area to the south. (1987, p.18)

The relationship between agricultural production and the nutrient pollution of Lake Okeechobee is generally accepted among the state regulatory agencies. This relationship has been disputed by some producers. They cite a long history of high nutrient levels and algae blooms in the lake. It is clearly more difficult to link the agricultural sector with a contribution of a generic substance, such as phosphorous, than it is in the case of a specific agricultural pesticide. Documenting specific agricultural impacts on wildlife, for example, may be even more difficult because of the need to separate agricultural from the urban-residential impacts.

As noted in Chapter 1 of the present study, scientific documentation does not exist on the biological impacts of newly expanding agricultural production in southwest Florida. That information gap will be partially filled by an upcoming South Florida Water Management District ecological study. If adverse impacts are documented, pressures could be generated to radically change technology or completely halt

agricultural development. If dramatic negative environmental impacts are not discovered, then technological changes will continue to be influenced at the margin by the ongoing requirements of the regulatory agencies. Eventually, effective pressure from producers may be exerted to drop regulations if the absence of documented negative impacts would persist into the future.

It is suggested here that intense pressure to change existing agricultural technology may be expected when a combination of 1) public and interest group environmental concern, 2) legislation and executive agency involvement, and 3) physical evidence or documentation of specific environmental impacts, all combine simultaneously. This has been the case, for instance, with the Lake Okeechobee problem where various best management practices, aimed at limiting nutrient pollution, have been urged on agricultural producers by regulatory agencies. The Okeechobee situation demonstrates the interaction between technology and institutions. The agricultural technology generates an adverse environmental impact which, when discovered and attributed to agriculture, must be mitigated by public agencies (e.g. South Florida Water Management District). A new modified technology then emerges from this interaction and that new technology may generate further adverse impacts. This is precisely the coevolution of a technology with its social and biophysical environments discussed in Chapter 2 of the present study. In southwest Florida, however, a complete

cycle of technology use, documented environmental impacts, and institutional reaction has not yet occurred. The concern of this chapter is the informational and educational role of the SWFREC in such a process.

In the U.S. and in Florida, there is some evidence of general public concern with the ecology and the preservation of wildlife. Duda notes:

> Recent public opinion studies reflect an overwhelming concern by Americans and Floridians for environmental, natural areas, and wildlife issues. Not only are people expressing concern for these issues, but they are also willing to sacrifice many socioeconomic benefits in order to protect wildlife and the natural environment. In Florida, where policy makers have shown a great deal of concern for environmental issues, it may surprise some that the public is getting even tougher and more resolute about environmental protection, natural areas, and wildlife conservation. (1987, p.10)

In reference to southwest Florida, there is a concern about agricultural development but it is possibly not a broad public concern. It appears most intense among environmental groups and regulatory agencies. One press accounts notes:

> The expected surge in citrus farming worries environmentalists and regulators. They fear that draining and dredging required to turn South Florida wetlands into citrus groves could pollute regional water supplies and reduce the habitat of wildlife. . . . The state Department of Environmental Regulation, the National Audubon Society, the U.S. Fish and Wildlife Service, and several other groups have recommended that the water management district go slow in issuing more permits until studies can be made of the overall effect of citrus. ("Move by Citrus to South Stirs Fear for Water" 1986, p. 6B)

It may require scientific documentation of adverse impacts of significant concern (e.g. drinking water well contamination)

to mobilize the general public. That could potentially lead to a demand for substantial change in technology or a halt to citrus development.

There is a significant amount of national and state legislation which is directed at environmental protection including the federal Endangered Species Act; the Federal Insecticide, Fungicide, and Rodenticide Act; the Florida Water Resources Act; and the Florida Wetlands Protection Act. Executive or administrative agencies involved with this legislation include the E.P.A., the Florida Department of Environmental Regulation, and the water management districts in Florida. The legislation and executive agency action has had, and will have, an influence on agricultural technology in southwest Florida.

Scientific evidence of environmental impacts of agricultural technology has occurred on a case by case basis (e.g. well contamination). Nevertheless, environmental agencies have often felt the need to take action without solid scientific documentation which links a specific technology to an illegal impact. Even though, in southwest Florida, there is a lack of scientific evidence of specific impacts associated with expanding citrus production, a major concern of producers in the region is that regulatory agencies do make decisions, which are costly to producers, without scientific evidence or documentation of impacts. The decisions of the South Florida Water Management District, in

particular, often require producers to modify their production technologies.

The objectives of this chapter are 1) to document the center's linkages to clients including clients' priorities, 2) to discuss the possible public interest implications of those linkages, 3) to demonstrate the influence of the South Florida Water Management District on agricultural technology and on the SWFREC, and 4) to consider a reorientation of the existing institutional and organizational paradigm, implying a more extensive and non-traditional set of researchable problems. The material in this chapter will help validate some aspects of the models presented in Chapters 2 and 3, most specifically the influences of the socioeconomic and political structure on technology. The exclusive linkage of the center to a limited client group will, in accordance with client economic characteristics and research priorities, have an influence on the nature of the technology developed at the center as the deJanvry model would suggest. Beyond the importance of client group linkages, the influence of the bureaucratic structure is evident. Water management district impact on agricultural technology exists because of a solid legislative mandate, public financial support, and a comprehensive regulatory framework including a detailed permitting process. The potential for conflict between client group and public regulatory objectives creates a possible stress on both the technology and the research organization.

## Clients and Priorities at the SWFREC

In the state of Florida, an expanded agenda for agricultural research was first proposed over a decade ago by policy makers at the Institute for Food and Agricultural Sciences (IFAS) of the University of Florida. In the 1975 document entitled "Agricultural Growth in an Urban Age" most of what is currently termed "the new agenda" was identified. Beyond the traditional production and marketing concerns, the report discusses agricultural-urban conflicts over water resources, land use, and taxation, as well as environmental problems and rural community development difficulties (pp.225-8). In reference to broad institutional objectives, the report states:

> We seek a growing and prosperous agriculture; an agriculture that can contribute its full share to the economy of the State; an agriculture that can supply an abundance of wholesome and reliable farm, forest and fishery products to consumers; and an agriculture that can be compatible with the total social and economic environment in Florida. (Ibid., p.7)

A concern with the compatibility of the agricultural sector with its wider social and biophysical context has more recently been an important theme for IFAS:

> The proximity of important agricultural areas to centers of urban population growth lends emphasis to the issues of compatibility. The concern with compatibility is being felt on at least three fronts: (1) in the alteration of the community's system of values; (2) in the use and preservation of the state's vital natural resources; and (3) in the changing political climate in Florida. All three have the potential to seriously affect agriculture in Florida. (IFAS 1986, p.245)

Given the situation in Florida, compatibility seems to be a necessary goal if the agricultural sector is to maintain its position or grow.

The role of IFAS is the generation of technologies and information in accordance with institutional goals. The function of IFAS is "to develop and disseminate information useful to the agricultural industry - including farming and other agricultural businesses - and to rural people" (1975, p.225). An emphasis on information generation and on the importance of the compatibility of commercial agriculture with its broader context is evidenced in the recent mission statement of the southwest regional center:

> The primary mission of the SWFREC is to conduct research to find solutions to problems hampering profitable agricultural production and marketing in Southwest Florida, and to implement extension programs to effectively convey these solutions to the intended clientele. It is important that the Center's recommendations reflect the necessity for agricultural production to remain compatible with the environment and urban development. (Arnold 1987)

The concern with compatibility would appear central to the planning of all research and education programs in Florida.

The present research would indicate that the acquisition of funding for the recent expansion of the SWFREC may be attributed to the combined political and legislative influence of 1) established regional producers, 2) producers moving south from other regions, and 3) long term southwest Florida landholders. Members of these groups are interested in developing regional land for production. During the 1970s

regional producers, particularly cattle ranchers, requested an upgrade of the research facility but did not have sufficient influence to secure the required public funding. An adequate support coalition of producers favoring center expansion was achieved following the hard freezes in the early 1980s which devastated citrus production areas in the central portion of the state and greatly increased incentives to expand in the southwest.

Favorable temperature conditions in the southwest have helped increase citrus and vegetable production in recent years while cattle production has decreased, in many cases through conversion of cattle land to citrus production. There has been some interest also among producers in developing sugar cane on the region's sandy soils. The future for sugar is closely related to the government price support program while other regional products do not have direct government support.

At the SWFREC, the operational aspect of research needs identification initially focused on selection of the disciplinary orientation of incoming faculty and on the sequential hiring pattern of those individuals. The more urgently needed positions were scheduled to be filled first. In a 1985 meeting of all of the commodity group advisory committees and 10 department chairpersons from IFAS, consensus was achieved that water management was the top priority issue. Competition from rapidly growing urban

areas, and resistance on the part of environmentalists to agricultural expansion, caused producer concern.

The water priority has been translated most directly into two faculty positions, one in water quantity and one in water quality. Both of these positions were among the first five to be filled, along with citrus and vegetable horticulturists and a plant pathologist. The second group consisted of a forage agronomist, range scientist, and a soil scientist. The last group in terms of time of hiring included an entomologist, a sugar cane agronomist, an animal scientist, and an agricultural economist. Some sense of derived priorities can be gleaned from the disciplinary nature of these positions and their relative urgency in terms of hiring. It is clear that common concerns focus on the necessary input of water which is additionally used for freeze protection and as a conduit for chemical inputs in low volume irrigation systems.

## Grower Advisory Committees

The SWFREC has established its primary client linkages with producers on a commodity basis. The producer groups, divided along commodity lines (i.e. beef/forage, citrus, sugar cane, and vegetable) are, as suggested in the Blase and Paulsen model, the basic linkages of the research center with larger society. At present, it is primarily the needs of these groups which define the goals of the research organization. The purpose of the advisory committees is "to advise

and assist" IFAS research and extension personnel in the implementation of regional commodity programs. In addition to being forums for exchange of information on the progress of the devel-opment of the center, the advisory committees have been sources for identifying priority research needs. In the context of the producer advisory committee meetings, specific research needs were discussed but were not clearly prioritized in all committees.

Information from the beef/forage committee indicates a wide range of needs across all aspects of ranch operation. Within the water category, water management techniques, improved environmental monitoring, and possible uses of municipal effluent were highlighted by the beef/forage committee. Apart from water issues, there is concern with improved quality forage, reduction of fertilizer inputs on improved pasture, cattle nutrition, alternative production practices, profitability and management, and marketing and consumer acceptance. An interesting aspect of regional cattle production is that calves are sent out of the state for fattening. This implies a relatively greater emphasis on younger animals and less on the characteristics of mature animals.

The water concerns of the citrus advisory committee relate to water requirements of trees, water application and drainage monitoring, comparison of types of irrigation systems, water table management, and the possibly inadequate water allocation scheme established by the water management

district. Other research needs include work on grove layout, bedding, tree nutrition, reset management, tree wraps, windbreaks, pest management with emphasis on biological control, and improved rootstocks. The concern of the committee is to obtain specific types of technical information from the center, including adaptations of technology to the southwest Florida context. Much of the work in citrus can be seen as technology adaptation from the production practices used in the central part of Florida.

The sugar cane research program of the SWFREC is devoted to production on sandy soils. Very little of the muck soils in the Lake Okeechobee area is actually in the five county region covered by the southwest center. Production of sugar cane on sand is a relatively unexplored area as compared with the many decades of accumulated research on muck soil production. The top priority of the advisory committee was clearly identified: "It was unanimously agreed by the Committee that our top priority and major efforts should be devoted toward fertility and water relationships in respect to profitable crop production" (Sugar Cane Advisory Committee 1986). A secondary need related to increasing sugar content without impeding vegetative growth. The committee ruled out variety evaluation as a priority for the SWFREC since adequate programs were being conducted elsewhere. The committee cites the faculty combination of water engineers, sugar cane agronomist, and the soil scientist as being crucial to their needs.

Finally, the vegetable advisory committee identified water and nutrition concerns especially the effects of nutrients and pesticides on water quality and salt toxicity from fertilization programs. Other research needs relate to the control of diseases (especially bacterial leaf spot), variety evaluations, control of insects, mites and nematodes, and cost and returns of alternative production practices. Disease control is more important than insect control but in both cases it was stressed that the possible banning of popular pesticides would create serious production problems. The vegetable committee noted that the development of alternative crops should not be a priority for the center but the "primary concern of growers is to receive assistance from SWFREC which will enable them to produce their major vegetable crops of tomatoes, pepper, cucumbers, melons, and squash more profitably" (Vegetable Advisory Committee 1987).

Grower Interviews

In the context of the present study further work was conducted to identify research priorities, particularly those related to water and the relationship between producers and the South Florida Water Management District (SFWMD). An attempt was made to learn about the producers operation in order to evaluate the relationship between the characteristics of an operation and expressed priorities. A total of 24 interviews were conducted with farm owners or hired production managers. The interviewees, as a group, own or

manage a production area including approximately 42,000 acres of citrus, 11,000 of vegetables, 18,000 of sugar cane, and 108,000 of pasture for cattle. The agricultural sector does include a small number of extremely large scale land owners (100,000 + acres), who are in the process of developing their holdings, and few small and medium scale producers relative to some other areas of Florida and the U.S. An effort was made to interview different types of producers including, for example, a 100 acre citrus producer.

The interviews were conducted in an informal manner. Five interviews were conducted in each of the center advisory committee categories ( i.e. beef/forage, citrus, sugar cane, vegetable) and four with relatively large scale diversified producers. Most producers were engaged in the production of more than one commodity. The interviews covered several areas including:

1) An overview of the producer's operation (crops and irrigation systems);

2) Discussion of the specific commodity category including: a history of acreage expansion/contraction, a review of experience with water management regulations and permitting, and opinions on various types of irrigation systems;

3) Experience with overall environmental regulation including endangered species protection and pesticide use; and

4) Research priorities for the Immokalee Center.

The background information was obtained to help understand the producer's perspective and possible reasons for selecting certain priority areas. It was made clear to the people interviewed that their stated research priorities need not be limited to the water area, but since that was the focus of the interview some bias might exist.

The following is a list of expressed research needs by commodity category. Each entry signified by a dash on the list refers to the statements of an individual interviewee. Lettered subentries indicate multiple responses with no relative priority implied.

<u>Vegetable Producers</u>

- Agricultural product marketing, specifically quality control.
- Drip irrigation feasibility.
- a. Insect control, fertilizer application.
  b. Wetlands monitoring coordinated through center rather than by individual growers.
- a. Relationship of water and pesticides.
  b. Semi-closed irrigation feasibility.
- a. Publications: production data.
  b. Soil testing services.
  c. Water quality and low volume systems.

<u>Citrus Producers</u>

- Improved root systems, disease identification.
- a. Improve perception of agriculture.

  b. Wetlands monitoring.
- Drip irrigation versus seepage regarding total quantities pumped.
- a. Water quality/quantity.

  b. Public education to improve perception of agriculture.
- a. Improved citrus root stocks.

  b. Blight prevention.

  c. Water use efficiency.

<u>Beef/Forage Producers</u>

- a. Water conservation/recycling.

  b. Improve quality of agricultural water discharge.

  c. Traditional production work.
- Priorities as identified by beef/forage advisory committee.
- a. Improved grasses. Selective destruction of smut grass.

  b. Alternative marketing for beef (low prices/little competition at slaughterhouse).
- a. Agricultural versus urban water use.

  b. Research to improve production intensity.
- a. Productive use of torpedo grass.

  b. Improved small feed grains.

Sugar Cane Producers

- Production on sandy soils.
- Water use and fertility on mineral soils.
- a. Water and fertility on sandy soils.
  b. Herbicide leaching and residue problems.
  c. Improve public perception of agriculture.
- a. Production on sandy soils.
  b. Labor issues, especially liability insurance.
- a. Fertility on sandy soils.
  b. Pest control.

Large Scale/Diversified Producers

- a. Net agricultural use of water versus urban use. Identification of total water resource.
  b. Production economics of citrus.
- a. Semi-closed irrigation feasibility.
  b. Consolidation of environmental monitoring at center.
- a. Economics of permitting process and environmental monitoring requirements.
  b. Consolidation of monitoring at center.
  c. Education to improve public perception of agriculture.
- a. Improve citrus root stocks.
  b. Control of viral diseases.
  c. More applied research and transfer of research done in other places/countries.

The background discussions indicated that most producers have a concern for being able to stay in business. Business survival depends on the ability to deal with the water and environmental issues as well as the usual difficulties and uncertainties associated with agricultural production and marketing. This suggests dual concern whereby survival is the first consideration, followed by the traditional concern for improving economic profitability or increasing the return to investments of physical and human capital. Notably, however, some producers in areas near residential development were looking forward to being able to sell their operations to take advantage of expected high land prices.

For the most part, the producers who are currently involved in expanding citrus production are those who have had the greatest degree of difficulty with water and environmental issues. The larger the surface area, size, and number of included wetlands in a proposed citrus development, the more the attention and lobbying of the environmental groups is focused on the water and environmental permitting process. However, both the large and the occasional small producer also face certain proportional "rules of thumb" whereby approximately 15% of the land surface must be reserved for retention areas and wetlands. The permitting process tends to be iterative with producers bargaining for more usable land and environmentalists pointing out the negative impacts of the proposed development to the regulatory agencies, principally the SFWMD.

Producers who have farmed in the region for many years have established certain prior rights, such as the use of Caloosahatchee River water and the ability to discharge to the river and manmade canals, which could not be currently obtained. Producers in some areas belong to special drainage districts which are controlled by the producers themselves and are only subject to district-wide inflow and outflow regulation of the SFWMD. Much of the environmental legislation includes "grandfather" clauses which allow existing opera-tions to engage in practices, such as seepage irrigation for citrus, which would not be allowed in a new development.

As a general rule then, producers who are most involved in expanding their operations are interested primarily in what the research center can do in terms of reducing the expenses and losses resulting from the water permitting process. The producers with established and nonexpanding operations tend to prioritize according to the traditional production related concerns. The traditional belief is that an agricultural "experiment station" provides specific research and services (e.g. disease diagnosis) which lead to productivity enhancement, usually yield per acre. The circumstances of conflict with the urban and environmental groups and the heavy regulatory burden have caused some producers to look to the SWFREC for research not directed at increasing profitability per se but at reducing agriculture's demand on the environment, for example, through water

conservation. It is also important to note that many of the producers interviewed expressed a concern for environmental preservation particularly as regards recreational uses (e.g. hunting and fishing).

The preceding discussion summarizes some of the concerns expressed by the clients of the SWFREC. A conceptual classification has been offered which distinguishes between research needs induced primarily by the regulatory environment and those related to the traditional production concerns. Because of the establishment of prior rights by some producers, it is the current agricultural land developers who have relatively greater costs associated with environmental regulation. Among the group of those concerned with developing agricultural lands are many of the large and influential landholders. Many of these same influential individuals are also closely associated with generating the political influence which was necessary to obtain the public funding for the expansion of the SWFREC.

It is clear that the future agricultural research program of the SWFREC will, to the extent that it does respond to external forces, be influenced by the linkages established with the commodity based advisory committees. As discussed in the previous chapter, the internal structure and incentives (e.g. pressure to publish) of IFAS and the center also play an important role in determining information output. The exclusive use of commodity based client groups presents several difficulties in terms of broadening and diversifying

the center's support base. First, because of the commodity orientation it is unlikely that alternative crops will receive much attention. As noted, the vegetable advisory committee explicitly downplayed the importance of alternative crops. Second, and possibly more important, the exclusion of "new agenda" groups (e.g. environmentalists, consumer groups, farm labor advocates) from the center's advisory framework does not provide a broad base of public support. The center may over time become too closely associated with the commodity producer groups, their concerns, and their present and future level of political influence. That eventuality could seriously undermine the public credibility of the center. A more inclusive coalition of client groups would suggest a different hiring pattern and a different set of research priorities. For example, a research staff geared to the needs of the "new agenda" might include such positions as a rural sociologist, a human nutritionist, and an ecologist. The organizational paradigm of the center has apparently been established in the traditional mode with a primary focus on the needs of commercial agriculture. Flexibility to address the "new agenda" issues, should social or political pressure arise to do so, may be quite limited.

## Public Interest Rationale

One of the most difficult issues in the planning of publicly funded research is determining an operational concept of the public interest. Legally, there is a public purpose

doctrine which states that "public funds are to be utilized only for the benefit of the general public" (IFAS 1986, p.351). The interpretation however is not straightforward:

> Because the public purpose doctrine is based on concepts of general welfare, there is no single definition that applies to all cases. The notion of general welfare changes continually with particular needs and pressures of the times. The parameters of the public purpose doctrine are not defined clearly, and every decision of public purpose should be examined in light of the facts of each situation. (Ibid., p 351)

In southwest Florida, the public interest is affected by benefits associated with agricultural development and the costs in terms of possible ecological damage from that development.

Scientists have taken great pains in claiming to avoid the intrusion of subjective personal values into their decisions about which research projects to conduct. Implications of subjectivity are at odds with value-free, objective science. There was a time when scientists were assumed to act in the public interest. In the current context of institutionalized science, it is clear that the scientist is very much influenced by the surrounding social and institutional environment (Busch and Lacy 1983). In addition, the public perception of technological advance as unambiguously good has been called into question because of associated adverse ecological and human health impacts. The necessity of guiding the work of scientists has posed a serious problem of specifying the relevant values.

Earlier, we noted that the typical recourse for value judgments for setting agricultural research priorities has

tended either to the market or to the legislature. Both avenues pose problems in light of the ubiquity of market and government failure phenomena. In the induced innovation model, research efforts are directed at saving inputs which have become relatively more expensive. The work of deJanvry and others demonstrates that the workings of the social structures of a country or region tend to distort market prices from their actual physical scarcity values; therefore, market prices do not represent value-free guidelines. The induced innovation model also ignores unpriced natural resource inputs and waste outputs which are critical in accounting for ecological values. Some of these phenomena will be felt at the SWFREC as producers seek information to reduce input costs. However, contrary to the relative price induced innovation model, producer needs are not axiomatically a reflection of the "public interest."

Recourse to the legislature for value judgments has, in the literature, taken the form of requests for the specification of a social welfare function or, in some cases, the implicit derivation of a social welfare function from the public tax structure or other public decisions. As far as the SWFREC is concerned, an operational legislative mandate has yet to be given to the center for priority setting in the presence of possible conflicting social goals. The Florida legislature has allocated $2.3 million for the construction of facilities and approximately $1.3 million per year will be needed for salaries and maintenance costs when the center

reaches planned strength. Generally knowing what type of benefits are expected for Floridians by the legislature as a result of this investment would provide some basis for addressing public interest and legislative intent. Knowledge of the underlying interest group motivations and public intent behind the development of the center is critical in focusing the research and education programs.

Despite the absence of clear legislative guidance, some decisions have been made which tend to implicitly reflect the expected future program of the center. The type of buildings constructed, the equipment purchased or budgeted for, the personnel hiring pattern, and the accepted linkage with commodity based producer groups all seem to imply a role for the center as essentially a service organization for the region's agricultural producers. It is important to consider if the success or failure of the center will ultimately be judged by the Florida legislature and IFAS primarily based on the level of satisfaction of the commodity producer groups.

Nationally, one of the historic strengths of the experiment station arrangement has been its geographic decentralization which encourages consideration of unique regional and ecological problems. While concern exists throughout the state of Florida to mitigate development impacts on the environment, the situation in southwest Florida may be particularly pronounced given the proximity to the Everglades and Big Cypress Preserve, and the presence of legally protected endangered species and wetlands. Regional social pressures,

particularly regarding the protection of environment, may be at odds with the profitability objectives of the producers. Indeed, to the extent that the SWFREC succeeds in enhancing the profitability of agricultural production, more investment in conversion of the region's undeveloped land to agriculture will be encouraged. Even with a perfectly benign production process, agricultural expansion does replace natural vegetation and natural wildlife habitats with rows of citrus trees and vegetables.

Clearly, the producers have the legal right to use their land as they wish within regulatory limits, such as those pertaining to water and pesticide use. They do not necessarily have a claim to public support of their efforts. In the past, the national public research system has largely helped existing producers adapt to changing economic and biophysical conditions. There has usually been a stated policy rationale for public involvement such as lowering food prices to consumers, preserving the family farm by improving farm income, or increasing productivity to free resources for other sectors of the economy. In the case of southwest Florida, the southwest center is apparently charged with the delicate task of helping producers expand into new and potentially sensitive ecological areas. This will involve enhancing competitive profits relative to other production areas in the state and elsewhere, and meeting the environmental regulations which tend to limit profitability.

The public interest rationale for the expansion of the southwest center lacks clarity and documentation in terms of legislative mandate. As detailed earlier, the center's direct clientele includes only commodity based producer groups and that brings into question the exact nature of the expected social benefit from agricultural research. Lawmakers in Florida have decided, apparently without the benefit of an ecological feasibility study, that public funds will be used to assist producers to expand into a region where the population is growing rapidly and the natural resource base has the potential to be degraded as it has in other areas of Florida. From a regional perspective, the economic benefits may not offset the environmental costs since "local agriculture rarely produces critical proportions of locally consumed products. Florida citrus, sugar, vegetable, and nursery production look to national and international markets, not to the local economy, as the destination for its output" (IFAS 1986, p.250). The center may eventually find itself working for goals that are at odds with some forces in the region's socioeconomy.

Earlier, the distinction was made between research needs related to environmental regulation and those related to the traditional production problems (e.g. disease, pests) in the region. Economically, the distinction is arbitrary from the perspective of a profit maximizing producer. Regulation comes from the social sphere while production problems are economic and biophysical limitations. Regulation results

from a social perception of adverse ecological impacts. The type of research which may be most compatible with broad regional interests is that which both mitigates adverse environmental effects and increases economic profitability. This has basically been the case with low volume irrigation systems in citrus which satisfy regulatory requirements in an economically feasible way. Improved efficiency in water and chemical application bridges possible incompatibilities between environmental and economic values. Integrated pest management has similar joint benefit characteristics. The public interest would seem well served by finding additional areas were interests overlap.

Some disciplinary specialties may find it relatively easier to address joint environmental and economic objectives. Water quality and quantity engineers have an orientation to reducing waste which means maximum economic efficiency of energy costs for water pumping and of expenditures for applied chemicals. The center's soil scientist, for another example, will likely receive information requests from both producers and regulatory agencies concerning nutrient and pesticide transport and fate. A portion of the other research needs and diagnostic services performed at the center may, however, be directly related primarily to economic profitability and the scientists engaged in this work will be closely associated with producer groups such as might be the case with the citrus horticulturist. This individual, according to the producer group priorities documented

earlier, will be requested to conduct research on citrus tree wraps, bedding and drainage, grove layout and so on. Some of this research has the possibility of being incompatible with protection of environmental values.

The expected social benefits from public support of the expansion of agriculture into southwest Florida are not obvious and have not been clearly established by the Florida Legislature or IFAS, the parent institution of the southwest center. The role of a publicly funded research center in a frontier area is not easily defined since all research geared to adapting production to local conditions could be appropriate. The overall public funding rationale to encourage a larger statewide planted citrus acreage would seem to require justification, particularly given significant citrus replantings following freezes in the central Florida area. For systematic research planning, the objectives of the investment in the SWFREC by the Florida legislature must be better specified.

In sum, the institutional analysis indicates that a potentially serious public interest problem exists if the center is defined as a regional resource. The primary client group that has been brought into the center's priority setting process is representative of commodity producers of the major marketed regional products. Other existing or potential new agriculturalists (e.g. urban gardeners or alternative crop producers) have not been included in identifying research needs. Neither has an array of other interested

parties (e.g. environmentalists, farm workers, county officials) with a stake in rural southwest Florida. The inclusion of these groups would, if the center wishes to maintain its own compatibility with the wider regional environment, appear to be a pragmatic necessity. Currently, it is largely in a derived sense, through an impact on the commodity based groups, that other interests are brought to the attention of the SWFREC.

## Water Management District Influence on Technology

An important step in the center's development is the establishment of linkages with client groups and the identification of client needs. The environmental regulatory situation in Florida is such that expressed client needs are, in some cases, almost totally related to meeting regulatory requirements particularly for those producers developing new acreage. Producers are often concerned that they will not be able to maintain economic viability with the technology required by regulatory agencies. Regulated technical requirements, such as specific types of irrigation systems, illustrate the influence the politico-bureacratic structure in the deJanvry model has on the evolution of a technology. The very active presence of the South Florida Water Management District (SFWMD) has led to the mitigation of some of the perceived ecological effects of agricultural production. The water management district has broad authority and a very

direct control of some aspects of production agriculture in the region.

The South Florida Water Management District is one of five such regional agencies in Florida which have been given a broad and powerful mandate by the people (via tax referendum) and by the state legislature. Following a severe drought in the early 1970s, the Florida Water Resources Act of 1972 was enacted changing the existing system of water law and bringing all waters under state regulation. The purpose of the Act was to set up an administrative structure to provide for comprehensive water management through planning and regulation. The legislative intent of the Act was:

> (a) To provide for the management of water and related land resources; (b) To promote the conservation, development, and proper utilization of surface and ground water; (c) To develop and regulate dams, impoundments, reservoirs, and other works and to provide water storage for beneficial purposes; (d) To prevent damage from floods, soil erosion, and excessive drainage; (e) To preserve natural resources, fish, and wildlife; (f) To promote recreational development, protect public lands, and assist in maintaining the navigability of rivers and harbors; and (g) Otherwise to promote the health, safety, and general welfare of the people of this state. (Florida Statutes, Sec. 373.016 (2) (a)-(g))

That Act interpreted waters in the state very inclusively:

> . . . any and all water on or beneath the surface of the ground or in the atmosphere, including natural or artificial watercourses, lakes, ponds, or diffused surface water and water percolating, standing, or flowing beneath the surface of the ground, as well as all coastal waters within the jurisdiction of the state. (Ibid., Sec. 373.019(8))

The Act authorized the five districts to engage in consumptive use permitting as well as the permitting of well digging and surface water management. Administrative, criminal, and civil enforcement of both the Act and the rules of the water management districts was also provided. Violation of the Act or a water management district rule is a second degree misdemeanor.

Subsequent to the passing of the enabling legislation itself two events have played, for our purposes, a very crucial role in the development of the districts. First, in 1976, a public referendum was passed providing for a special independent taxing authority, within legislated limits, for the districts. This has exempted the districts from the normal state budgetary process and, in the case of South Florida, has provided reliable and adequate funding to conduct wide ranging and annually expanding programs. Second, court challenges to the constitutional status of the provisions of the Act, most specifically the permitting authority, have been decided in favor of the districts. The main contention of the court challenge was that the denial of a consumptive permit constituted the taking of private property rights without compensation. In the Village of Tequesta v. Jupiter Inlet Corporation decision the Florida Supreme Court ruled that no right to water ownership existed under common law. There was a use right to water subject to the criteria of reasonable and beneficial use. It was left to the districts to apply the reasonable beneficial use criteria in

issuing permits. The definition of reasonable beneficial is "the use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner which is both reasonable and consistent with the public interest" (Ibid., Sec. 373.019 (4)). The Act provides further general criteria for determining reasonable beneficial use; however, on a case by case basis subjective judgments regarding the "public interest" must be made by the districts. That subjective authority has not successfully been challenged in court, but there is reason to believe that some district action is beyond the scope of an administrative agency (Florida House of Representatives 1983).

The SFWMD's water use and surface water permitting process for the agricultural producers has been criticized by regional producers because of the complexity, expense, and subjectivity involved. The difficulties with this process are the source of many of the expressed research needs discussed previously in this chapter. It is important to reemphasize that agricultural land developers are most affected by permitting problems whereas established operations are typically granted permit renewals with minimal difficulty. The establishment of a permit constitutes, in a sense, a priority use which cannot be interfered with by potential new users. The relevant district rule states:

> The proposed use of water must not cause an unmitigated adverse impact on a legal use of water existing at the time of the permit application. An adverse impact is defined as a decrease of

> ten percent or more in the withdrawal capability of any presently existing legal use. (SFWMD 1985, p. A-12)

This is only one of the many criteria provided in the legislation and employed by district permitting authorities. Other important considerations for a proposed use are that it does not 1) encourage salt water intrusion into the freshwater aquifer, 2) adversely impact off site land uses, 3) cause adverse environmental impacts, and 4) contradict state water policy.

Permitting a new agricultural development, for example a citrus grove, is at present an extremely expensive and time consuming process. Both a consumptive use and a surface water management permit must be obtained. Even for a modest development (e.g. 100 acres) a professional engineer is usually required to conduct the necessary tests and provide documentation. Particularly with the larger developments many rounds of information exchange are needed between the permitee and the district, particularly in cases that attract the attention of environmental groups and state environmental agencies. Essentially a bargaining process takes place. The permitee attempts to prevent additional lands from being taken out of productive use while environmental groups and state agencies call various types of expected adverse environmental impacts to the attention of the district's permitting bureau.

The consumptive or water use permitting process requires the submission of a comprehensive application form describing

planned location, crops and irrigation systems, existing usage, adjacent usage, water conservation measures, freeze protection requirements and other legal and administrative information. The process also requires the permitee to document, at the permitee's expense, that the proposed use is consistent with the criteria cited above. The district may require that various hydrological tests (e.g. salt water intrusion test, aquifer performance test) be conducted by registered professionals to determine potential development impacts. The final approved permit contains clauses which extend the permitee's responsibility to mitigate eventual adverse impacts on other users or on the environment. It might be noted that the information on crops and irrigation systems provided by the permitee is used to determine the water allocation based on reasonable need. Various methods are employed to calculate the irrigation allocation; however, in the case of citrus, the district-wide standard has been set at 5.3 inches per month. There has been some controversy over the allocation procedure, but since there is no enforced metering in effect, the allocation exercise has to date been somewhat academic.

For a new development, a surface water permit is also required and is issued in conjunction with the water use permit. The proposed project review process focuses on the impact of a project on adjacent lands as well as on the change in the on-site environmental values. As with the consumptive use, the objective is to maintain the status quo

relative to adjacent users and the surrounding environment. This means that surface flows should not be blocked and that quantity and quality of flows should be maintained as closely to the pre-development state as possible. The district employs certain criteria to accomplish this including, for instance, that a new development should be able to pass the surface flow of a once in 25 year-3 day flood event through or around the project thereby maintaining the pre-development flow situation. In terms of water quality, the requirement is that a site be able to detain the runoff from a 2.5 inch rainfall. To meet the surface water management requirements, it is typically necessary to construct on-site storage which can also perform other functions such as being part of a wetland mitigation process. The engineering plans for a project's water management system are submitted as part of the district's permitting process.

The issue of the maintenance of on-site environmental values is less subject to engineering solutions. It relates to the preservation of on-site wetlands and the fish and wildlife, particularly endangered species, which depend on those natural habitats. Surface water management design is required to preserve the larger wetlands intact and free from encroachment by access roads or rights of way. This requires a system of water table control which allows a higher table for the wetlands and a lower table for nearby production areas. As stressed earlier in the present study, the issue of water table control is a critical one that has attracted

environmentalist attention for many years. The problem is summarized by a SFWMD environmental official as follows:

> The increasing trend to convert the low pasture land of southwest Florida to citrus groves has raised another concern - environmental protection of wetlands. The low hammocks and flatwoods are interspersed with cypress heads, deep marshes, and broad, shallow wet prairie. Wetlands have remained relatively undisturbed in the rangelands. . . . Cattlemen have been able to successfully raise beef without over draining the land. With the advent of citrus, however, lowering of the water table, combined with bedding of the groves, was necessary. Due to the shallowness of many of the wetland systems in south Florida, lowering the water table generally dries them out to the point that they no longer function as wetlands. (Helfferich 1987, p.5)

Further difficulty has arisen in production areas where there is large number of small (i.e. less than 5 acre) wetland areas. The ecological values of these areas cannot realistically be preserved in the midst of large scale developments. A series of district rules for mitigation has been developed for the smaller isolated wetlands whereby it is possible to leave wetlands unprotected if natural lands elsewhere are set aside.

One of the more prevalent recent conditions attached to the district permits requires wetland monitoring which is designed to track changes in native flora and fauna in the wetland area. As noted earlier in the chapter, one of the research needs often cited by producers was for a representative wetland monitoring project to eliminate the needs for each producer to undertake monitoring individually. One of the major concerns with wetlands monitoring has been

determining cumulative impacts. The Florida Department of Environmental Regulation has noted that conversion of acreage to citrus creates a "most serious concern" which is not seen in a project by project analysis. A south Florida DER official states:

> A comprehensive analysis of all potential impacts cannot be achieved if these projects are reviewed separately. Mass conversion of wetlands and uplands to citrus in south Florida could impact the quality and integrity of proximate Areas of Critical State Concern, the Save Our Everglades Program, and endangered species. (Benyon 1986)

It is worth restating that south Florida contains unique land types (e.g. cypress swamps) and endangered species including the Florida panther. The panther has been the subject of strong statewide concern. A significant public investment has been made to preserve the Florida panther including an extensive monitoring program and construction of highway underpasses in certain areas.

The environmental protection program of the SFWMD is oriented to requiring that producers limit, to the extent possible within the engineering "state-of-the-art," the on-site and off-site impacts of agricultural production. An absolute standard of wetland or endangered species protection would not allow any agricultural development. Even totally discounting the changes in water quantity and quality flows, the fact remains that the natural vegetation of southwest Florida is replaced with citrus trees in the course of development. One of the lessons of the discipline of ecology is that natural processes can be easily disturbed particularly

in sensitive subtropical areas. Since absolute standards are not possible, the district is in a position where it must attempt to balance the provision of water for current competing reasonable beneficial uses with environmental protection. It does this without clear legislative input on prioritization of competing uses. The district is the major growth management agency in the region.

## Water Management District and Research and Education Center Interaction

Because of the size and growth rate of the tax base in South Florida, the South Florida Water Management District has a substantial source of funds (SFWMD 1988). The district's budget has grown from $60 million in FY 85 to $143 million for FY 88. Over 200 new employees were added during the 1985-88 period. Because of the tax base growth it was possible in FY 88 to lower the millage rate while increasing the district's overall budget. In addition to expenses associated with the regulatory bureaucracy, a good portion of the district's budget is directed at the maintenance and operation of water management structures and canals in southeast Florida. The district has inherited a heavily engineered water management system and is attempting to reverse some of the adverse ecological effects of earlier water projects such as the channelization of the Kissimmee River. By and large the vast majority of district attention is focused on the water problems of southeast Florida. In

addition to problems with Lake Okeechobee and the Kissimmee River, other prominent concerns surround the continued provision of water to the large southeastern urban areas and the maintenance of appropriate quantity and quality flows to Everglades National Park.

As another component of its program, the district does some hydrological and ecological research. It also contracts research to consultants and other agencies and, as discussed, requires permitees to provide various types of permit and monitoring information. It is in the process of accumulating a data base for use in permitting decisions. Preliminary work has been completed, for instance, to try to explicitly model the hydrology of south Florida while more specific and detailed studies have been done in smaller areas where competition for water is intense. Ecological research has focused largely on documenting flora and fauna population changes, notably changes in wading bird populations. Along with the panther, the wood stork is another of the endangered species attracting much public concern.

In cooperation with IFAS and other research and education centers (e.g. Belle Glade) the SFWMD is funding a number of research projects of concern to Florida agriculture. Notably, a significant amount of research has been focused on approaches to reducing phosphorous runoff from dairy operations into Lake Okeechobee. The runoff is thought to be the reason for large algal blooms in the lake which can destroy fish populations. Best management practices have been

formulated to help curtail nutrient runoff. Other research has attempted to mathematically simulate regional irrigation requirements on a crop and soil type basis.

In southwest Florida, a cooperative research relationship has been established between the district and the SWFREC. There is, for the uses and purposes of both organizations, a very limited amount of available research on water use and environmental impacts in the expanding agricultural areas. Both organizations are intensifying their involvement in the region for essentially the same reason and that is the rapid expansion of regional citrus production. Operationally, the citrus expansion manifests itself to the district in the form of a large influx of permit applications for new acreage. District decisions must be taken without much background information. The district has, therefore, found it advantageous to invest in research at the southwest center and the center has been eager to put its expanded facilities and staff to use by tapping the available source of funds. The roles of the two publicly funded organizations are, however, quite different with the district regulating the activities of the producers who are, in turn, the support base and clientele of the southwest center.

One of the major objectives of the SFWMD with respect to the agricultural sector is the promotion of low-volume irrigation systems for water conservation. Its objectives for agricultural water demand management are: "To gain general acceptance of low volume irrigation techniques as state of

the art technology where feasible and to reduce the demand for irrigation water to a level consistent with the most efficient amount necessary for the crop" (SFWMD 1986, p. 5). The district has a two stage approach for each crop category. It initially focuses on the demonstration and promotion of the low volume systems which is then followed by requiring the use of low volume for all district permits on the given crop.

In the case of citrus the first stage was not necessary. The low volume irrigation systems were readily accepted by producers and have become a de facto district requirement. The technical characteristics of the low volume systems are consistent with the horticultural aspects of citrus and with profitable production given the typical economic position of the producers. The initial installation costs of the systems are significant (about $500/acre). Relative to seepage irrigation, citrus producers cite lower pumping costs, more efficient and timely water and chemical application, and less required physical labor as major advantages of low-volume systems. By contrast, low volume has not been readily accepted in the cases of vegetable and sugar cane production. The investigation of the feasibility of low volume irrigation on these two crops has been the basis for initial cooperative research between the SFWMD and the southwest center.

One of the first major research projects conducted at the expanded center is a preliminary evaluation of drip irrigation on tomatoes and sugar cane, funded in its first crop

year phase for $112,000 by the the water management district. The traditional method of irrigation in these crops is seepage which involves the conveyance of water through open ditches and which is considered low use efficiency because of losses to evaporation and deep percolation. Drip irrigation provides water directly to the plant's root zone through a system of plastic pipe and tubing. The ability to make water applications frequently and in low quantity means higher efficiency in water use. The project involved the production of the two crops with both seepage and drip irrigation systems. The project was conducted on station using small plots and high levels of professional management input. There has been concern among the producers that project results would be used to justify the requirement of low volume systems by the water management district. However, the SWFREC has been careful to stress the preliminary nature of the results. Preliminary results indicate that the low volume systems will not be economically feasible for sugar cane production.

The cooperative relationship between the district and the southwest center may be expected to continue in the future and be particularly strong in the water engineering and soil science disciplinary areas. The technical engineering orientation of the district corresponds well with the traditional nature of disciplinary research in those specialties. In the area of water engineering, various types of projects or experiments are being considered at SWFREC

including work on problems related to the high water table. The general objectives are in the area of eliminating technical barriers to low volume adoption in vegetables and sugar cane and of ultimately working out efficient irrigation and fertilizer application procedures. Discussions are proceeding concerning the on-station construction of a water retention pond of the type required by surface water permitting regulations. The district has expressed an interest in the provision of funds for the ecological monitoring of such a pond. Finally, it may also be expected that, in light of the district's approach to the Lake Okeechobee problems, future funding may be available for studies on the transport and fate of fertilizers and pesticides in the soil and aquifer.

The SFWMD has adopted a "carrot and stick" approach to the agricultural sector. Its first aim is to demonstrate and promote specific techniques within the overall production process. After demonstrating the viability of a technology, the district uses its permitting authority to require the use of the technology. It has initially concentrated on water conservation but has not faced any serious problem with the adoption of the low volume systems by the citrus industry. For a variety of reasons this has not been the case with other regional crops. It is not clear what the district would consider conclusive evidence of the economic viability of low volume irrigation for a given crop. It remains to be seen whether low volume will be required on new vegetable and

sugar cane acreage and particularly whether retrofitting of existing acreage will be required for permit renewal.

The SWFREC could potentially be in a sensitive situation if the relationship between the district and the center is perceived as detrimental to the interests of the producer groups. The district may be able, with relatively small amounts of project funding, to coopt a large portion of the center's research program including the time of several key disciplinary specialists.

## Case Study Summary

This analysis has attempted to show that there are internal and external institutional influences which tend to seriously hinder a systematic research planning process at the research center level. The combined institutional influences have, within a fairly narrow range of choice, predetermined what is expected of the SWFREC and what kind of research will be conducted there. The early work undertaken at the southwest center has proceeded in a predictable manner consistent with the traditional agricultural research paradigm. Relationships with the traditional clients have been firmly established. The expected disciplinary specialists, given the nature of the agricultural clientele, are being hired. The organizational mission of "helping producers" has been implicitly adopted and projects or experiments are underway to address regulatory and biophysical limitations to enhanced profitability. In some

cases, it has however been possible to combine profitability oriented research with research important for the preservation of natural values, such as with water conservation. Available funding from the well-financed SFWMD has been tapped as have producer in-kind contributions. No substantial organizational innovations have been made to help deal with the fact that the external social and bio-physical environment of the center is appreciably different from that in which the traditional experiment station model developed and flourished in other parts of Florida and the U.S.

In Chapter Two an attempt was made to apply a systems approach to technology and technical change. A conceptualization was provided for the external environment of a technology as well as for its internal characteristics. We have seen how the external social system influences and interacts with the development of technologies. The institutional impacts on technology, described in the deJanvry model, are particularly clear. In our case study, the Florida legislature, IFAS, the SFWMD, and the southwest center itself are all influential public agencies. We have focused most specifically on the role of the SWFREC showing how institutions, organizations, and groups interact with it to channel technology in a certain direction.

The role of the biophysical environment has not been as extensively developed as has the social and institutional role. It has remained in the background primarily because of the lack of documentation of ecological impacts of expanding

citrus production. It is not possible to discuss the scientific evidence from the biophysical realm which, through regulation, causes technology to evolve as has occurred in the Lake Okeechobee region. What may be said is that the diverse nature of the biophysical environment in southwest Florida may limit the transfer of research results and specific technologies from other production areas in the state or the nation. The heterogeneity of soil and water conditions across relatively small distances is a problem often encountered in tropical and subtropical ecosystems. Technology development for southwest Florida must deal with the sandy soil conditions, the high water table, and the dry and wet season phenomena on a crop by crop basis. Technologies developed in other areas will be successful in certain limited circumstances such as in the case of low volume irrigation on citrus.

Similar low volume technologies were discussed in the context of water permitting, and it was noted that the low volume systems on citrus were quickly adopted by producers whereas those for vegetables and sugar cane are, because of problems, far from widespread voluntary adoption. One of the more widely discussed technical problems on tomatoes, for example, is the sudden rise in the water table from rainstorms which chokes off the deeper rooted tomatoes produced under low volume. In the case of sugar cane there are a number of technical concerns relating, for example, to rat destruction of irrigation tubing. No generalization can

therefore be made across crops for a specific type of technology.

Some differences in adoption exist because of the biological nature of the citrus tree versus that of vegetables and sugar cane. Differential crop interactions with the biophysical environment must be considered. Aside from the technical concerns, the nature and economic position of the potential adopter is also important. Retrofitting existing operations requires different economic circumstances than adoption for new operations. In addition, well-financed large scale citrus developers have a much longer time frame for the recovery of investment than do smaller scale vegetable producers. Vegetable production is, because of the vagaries of the weather and the extreme perishability of the crop, one of the riskiest agricultural enterprises. New vegetable technologies will be best received which are risk reducing and at present low volume irrigation is risk increasing primarily because of the drainage problem.

The generation of technologies whose internal characteristics match the external social and biophysical environment is facilitated by innovation producing institutions which systematically consider both the social and the biophysical environment. One of the most direct and inexpensive ways to obtain an understanding of the social environment is to open the institution or organization to the influences and advice of a wide variety of social interest groups and public agencies. A representative advisory group can help reduce the

need for social science research to identify the research priorities of groups and public agencies normally outside of the traditional problem identification process. In our case situation, both at the institutional level (i.e. IFAS) and at the organizational level (i.e. SWFREC), access to the research priority identification process has been limited largely to commodity based producer groups. IFAS has made an effort in recent years to explicitly include the environmental concerns, but not necessarily the environmental groups. SWFREC could move to bring regional environmentalists, water management district personnel, or others onto the center's advisory committees. Change of orientation at the center level would seem to be possible, particularly with complementary change at the institutional level.

The development of a wide and strong base of support for continuing the institution of publicly funded agricultural research is in the interests of IFAS, the SWFREC, and the producers. McDowell has recently addressed this issue:

> Unless the non-traditional clients can be served by research and extension and their support organized in coalition with agricultural interests, the system may not be able to make the adjustments necessary to continue to serve even traditional audiences. . . . Traditional clients tend to ignore their declining capacity to deliver support when staking their claim to what resources still do exist. Unless they change their strategy - unless they build coalitions with new clients and insist that new clients be served - the social contract that made these institutions great will simply pass into history. (1988, p.21)

McDowell has taken a different perspective from the usual notion that the public agricultural research establishment

has to first and foremost serve the needs of the basic commodity support groups and, at peril, reach out to other groups.

In the future, the commodity groups at the national, state, and regional levels may, in order to maintain public support of the agricultural research system, find it necessary to adopt a broader conception of what is in their self interest. This would include a willingness to sacrifice some short-term profitability oriented research to address some of the issues of broader concern in states and rural communities. In Florida, a new orientation may require joint cooperation on the part of IFAS and producer groups to formulate a plan to substantially enhance the compatibility of producer priorities with the broader social forces at work in the state. A primarily open relationship between IFAS and the SWFREC, commodity producers, and social groups representing the broad public interest does seem to be a healthy long-term strategy for the maintenance and growth of the agricultural sector which is a goal for both producers and IFAS faculty.

# CHAPTER 5

# RECOMMENDATIONS AND CONCLUSIONS

## Context Summary

The social and biophysical environment of southwest Florida is unique and dynamic, and may require a highly innovative approach to the structure and functions of the Southwest Florida Research and Education Center. The entire package of social and biophysical conditions present in southwest Florida is not common in the United States. It includes potentially intense public environmental concern, a rapidly increasing regional population, dramatically expanding agricultural production, and difficult biophysical conditions for agricultural production. Elsewhere in the state and nation, some of the individual elements may exist in any given situation. The environmental concerns are potentially volatile in southwest Florida because of past incidences of agricultural pollution of drinking and surface water in nearby areas (e.g. Lake Okeechobee), the location in the region of the Big Cypress National Preserve, and the presence of several endangered species including the Florida panther and wood stork. Rapid population expansion is reflected in the fact that two of the first three fastest

growing cities in the United States are located in the region. The agricultural expansion is concentrated in citrus production which has approximately doubled in the last two years. Finally, the biophysical environment is characterized by sandy soils of low nutritive quality, a generally high water table with areas containing legally protected wetlands and swamps, and periodic rainfall extremes which can cause both localized flooding or water shortages according to the season.

## Recommendations for IFAS/SWFREC Consideration

### Background to Recommendation 1

In planning the research program at the SWFREC the first logical question concerns the legislative rationale for the public funding of the center itself. This relates to the nature of the expected public benefits from agricultural development in southwest Florida in light of the circumstances cited above. This research failed to discover public documentation relating to this question. It is difficult to chose between priority alternatives in overall research planning without general guidance from a legislative mandate.

Some of the rationales for the public funding of agricultural research in other areas of the country relate to the preservation of the family farm, the insurance of low priced food to consumers, and the maintenance of strategic

food supplies. Because many of the region's producers, particularly those who are actively engaged in citrus development, are large scale agribusiness operations the "family farm" rationale may not be relevant. The rationale of increasing production to maintain low food prices, both in the sense of increasing total planted acreage and in productivity per acre, appears to be a possibly relevant one. The consumers who benefit from the lower prices are a large and diffuse group, most of whom are outside of the southwest region and many of whom live outside Florida. In the early 1980s, hard freezes occurred in the central citrus producing areas of the state reducing total production and increasing prices. There may be a strategic economic reason, such as the maintenance of domestic source flows to the processing industries, for encouraging agricultural production in the less freeze prone southwest Florida.

Recommendation 1

It would appear important for the SWFREC to ascertain the explicit legislative rationale for the funding of the construction and maintenance of the center. The $2.3 million for construction and the anticipated $1.3 million for annual expenses (e.g. salaries, maintenance) was allocated at the opportunity cost of other possible public projects. The expected public benefits from that investment would help focus the research program along the lines of legislative intent. Of greatest importance would be any information on

the tradeoff between, on one hand, increasing production, and its benefits, and on the other, the ecological preservation of the region. The act of requesting this information could spur legislators or legislative committees to provide some helpful public interest guidelines, if none presently exist. It would at a minimum alert policy makers to the problem. Guidelines have been provided to water management districts which help them determine the legislative intent of "reasonable beneficial" water use.

Background to Recommendation 2

IFAS appears to have made an implicit interpretation of the legislative intent of the funding of the SWFREC. Two fundamental related "control" variables in the research planning system have been identified. The first variable is the selection of the center's linkage or client groups and the second is the selection of disciplinary and commodity specialists to staff the research center. In the initial development of the center, commodity based producer groups have been identified as the clients and the disciplinary and commodity specialists best suited to meet producer needs have been programmed for the staff. The selection of the client group and staffing decisions and plans, along with the type of facilities constructed, all seem to implicitly indicate that the primary purpose of the SWFREC is to help expand agricultural production into new areas and to enhance productivity of planted acreage to the greatest extent

possible. The latter goal has historically been a primary national goal for public agricultural research.

Criticisms of the public agricultural research system have been discussed here under the rubric of the "new agenda" for agricultural research. The "new agenda" suggests that the public, nationally, is concerned with a number of problems that have been directly or indirectly the result of the way in which the research system has in the past helped increase production. The displacement of labor through mechanization and the negative environmental effects associated with high chemical use are examples of "new agenda" issues. As noted, in southwest Florida the environmental concerns are potentially strong as are the conflicting needs, because of poor soil conditions, for high levels of chemical inputs. There appears to be a potential inconsistency between 1) facilitating the expansion of production areas and increasing land productivity and 2) responding to the concerns of the nonproducer population of southwest Florida and the larger environmentally conscious public. There is, in addition, the possibility that the SWFREC, while helping make development more attractive, will be working at cross purposes with some state environmental agencies (e.g. Florida Game and Fresh Water Fish Commission) which tend generally to oppose agricultural development in the region.

Recommendation 2

IFAS may wish to consider a reassessment of its program for the southwest region. It may be possible to make the program more compatible with the region's social and biophysical environment. This would involve an innovative break from the traditional "experiment station" model. IFAS could consider expanding the SWFREC support base through encouraging the direct advisory committee participation of a variety of regional groups, in addition to the traditional producer constituency which comprises the current advisory framework. Associated with this change could be a reevaluation of the disciplinary specialists designated to staff the center. This may require staffing from university departments outside IFAS.

Possible new advisory committee members might include representatives from environmental groups, coastal urban areas, the town of Immokalee, and regional public agencies including the SFWMD. More inclusive advisory committee representation, if it is to be effective, will require an associated innovative mix of disciplinary specialists. Clearly, given the situation, it would be important to have a wildlife biologist and wetlands ecologist on staff. Other disciplinary possibilities could include environmental engineering, political science, rural sociology, regional planning, and human nutrition. This reorientation would allow the center to fill research needs in areas, such as ecological impact, that are increasingly the domain of

private consultants. A more inclusive approach is also an important component of maintaining the independence and public credibility of the center.

Background to Recommendation 3

The biophysical production conditions in southwest Florida are such that some technologies are adaptable from other production areas outside the region. The irrigation system for citrus is an example of an adaptable technology. The same type system for other crops (e.g. vegetables) has not been adapted to the point of widespread use. The social environmental concern, and the unique nature and limited size of the southwest Florida ecological zone, may present an impediment to private enterprise involvement in traditional areas of private research (e.g. mechanical technology, chemical inputs, materials, irrigation systems). This problem could be exacerbated if a drastically different set of environmental regulations evolve in southwest Florida than exist in the rest of the state and nation. The private incentive problems associated with risky research for a limited and unique zone may cause increased pressure on the SWFREC to provide a full spectrum of research and information services including those provided by private input suppliers in other locations. For this reason, as well as the close center to producer group linkage, the distinction between private and public research may become blurred.

Recommendation 3

IFAS and the SWFREC may want to consider innovative ways to develop cooperative relationships with producer groups. For example, those groups could formally compensate the center for facilities and staff time employed in research that is geared primarily to the economic profitability of the producers. It would seem appropriate for the center to be compensated for work on citrus tree wraps, grove layout and bedding, and improved sugar content in cane. In contrast to that type of research, justification for the expenditure of public funds would seem to be stronger for work on new technologies to limit agricultural production impacts on legally protected endangered species and wetlands. Work on the agricultural utilization of sludge from urban areas, as well as work for client groups that are unable to pay, would also seem within the public realm. Some research, such as that on water conservation, has both private profitability and environmental protection benefits. It is naive to think that all research will fit this latter category.

Background to Recommendation 4

The South Florida Water Management District is an exceptionally powerful and well financed organization. It holds legal support for its decisions and also has a significant source of funding for its activities. It displays wide ranging objectives including environmental enhancement, flood control, water quality protection, and

water supply. The district's objectives for water demand management focus specifically on the promotion and eventual requirement of low volume irrigation systems across all the region's crops. The district has adequate funding to carry out research related to low volume irrigation. Because of the ecological uniqueness of the region few, if any, spill-over applications to other geographic areas can be expected from low volume research in southwest Florida.

Recommendation 4

Because of available funding, there is a danger of a dependent association with the SFWMD, just as there is a similar danger relative to producer groups. The SWFREC could develop a specific research plan and accept SFWMD funding for only those projects that fall within the independent plan. As the growers have pointed out in the context of the present research, the district shows little understanding of the agricultural enterprise. It would entail the loss of the objective expertise of center researchers to strictly follow priorities set by non-experts at the district. The general goal of water conservation is shared by both organizations; however, the specific approach on a crop by crop basis is best determined by center researchers. For instance, it would not appear productive to pursue the stated policy of the SFWMD in low-volume system adaptation for all crops in all locations. Other systems such as semiclosed irrigation

show promise for some crops as does a combination of low-volume and traditional seepage systems.

## Recommendations for Further Social Science Research

### Recommendation 1

The development of agriculture in an ecologically sensitive region poses a number of problems which can be illuminated by a regional social cost-benefit calculus. The Florida Legislature has made an implicit social cost-benefit determination in funding the SWFREC. If we accept the regional geographic boundary as the relevant one, then the balance between the benefits of agricultural development (e.g. employment, regional consumers' surplus) and the costs (e.g. environmental disturbance, exploited labor) merit explicit consideration. There is a hypothetical spectrum with the regional benefits exceeding the costs on the "good" end and the reverse on the "bad" end. Unfortunately, the calculation is not directly reducible to monetary values, especially regarding the environmental issues. Research on the willingness of regional residents to pay for ecological preservation would be important. Some regional residents, for example, would presumably be willing to forego the consumption of citrus products grown in the region if interior lands would be preserved in a natural state. It is difficult to identify the regional product among various

other market sources which expands the scope of concern to inter-regional, interstate, and international trade.

There is need for further social science research which might help elucidate the social cost-benefit calculation for agricultural development in the southwest region. Criteria might be developed for areas which have a development versus preservation balance to maintain. More rigorous investigation is needed. However, there are some elements in the southwest Florida situation that might suggest that the bulk of the income benefits from agricultural development, particularly citrus development, may accrue to a limited number of large scale developers and senior managers. While a number of middle level grove manager positions are becoming available, the vast majority of employment is low wage farm labor. The presence of the large volume of seasonal low wage labor has created a negative externality in terms of conditions in the economically depressed town of Immokalee where the bulk of manual laborers reside. Growth management officials in other areas of Florida might not encourage a private business to locate in their areas if that business promised mostly minimum wage jobs while potentially causing negative environmental impacts. If agriculture does not have significant benefits for a region it would seem appropriate to consider treating it as any other business. Further understanding of current relationships among labor and producer groups, along with consideration of alternative future scenarios, might help anticipate necessary research

policy measures for sustainable agriculture relative to both natural and human resources.

Recommendation 2

IFAS exhibits a long history of involvement with agriculture in southeast Florida, dating to the opening of the Belle Glade center in 1921. Some of the lessons learned there may possibly be instructive for the southwest region. It would seem that the SWFREC could profit from an analysis of IFAS involvement in the Belle Glade-Lake Okeechobee area. The Belle Glade center participated in the agricultural development of an area with soil conditions (i.e. muck) that are unique in the state. Research there has been location specific with little opportunity to utilize results from elsewhere or export results to other areas. A good amount of research has been conducted in the private laboratories of the large sugar cane producers. The division at Belle Glade between private and public research possibly may be illustrative for southwest Florida. The relationships with client groups and with the water management district might also be instructive. The position of the Belle Glade center in the controversy over the agricultural pollution of Lake Okeechobee by regional producers could have direct relevance to the SWFREC. Whatever problems have arisen at Belle Glade might be avoided or reduced. Following study of the Belle Glade-Lake Okeechobee area, parameters for research to

address the southwest Florida situation should emerge for consideration along with those unique to southwest Florida.

## Recommendations for Discipline-Related Research

### Recommendation 1

The approach in this research has presented a theoretical framework (Ch. 2) which describes the full array of potential inducement agents on the development of technology. It is essentially a systematic expansion of the simple concept embodied in the relative price based induced innovation hypothesis. The approach differentiates the internal characteristics of a technology from the external environment. In the case study examples, relatively greater emphasis in this research is given to the external environment, particularly the influences of the innovation producing, the legislative, and the administrative institutions. The unique nature of the southwest Florida ecosystem has been discussed but not in great detail. This research does not provide a detailed approach to the identification of the internal characteristics, complementarity, and rigidities of agricultural technology and how those might be quantitatively classified. It would be worthwhile to further investigate the Georgescu-Roegen production process model. A purpose would be to determine how the model can be better used in priority setting and in the development of new

technologies which will, more closely than existing technologies, match the external environment.

Recommendation 2

Paralleling the systems conception of technology, we have presented a rudimentary systems concept of agricultural research institutions and the organizations within those institutions. Internal institutional rigidities and incentives (e.g. pressure to publish in disciplinary journals) seem to isolate these institutions from many of the demands and influences of the external social environment. Thus, much of the research produced is unrelated to the needs of the social environment. Hence it tends to lose its historic innovative character and often becomes routinized. There would appear to be some parallel with a young innovative private company which, as it matures, becomes less innovative and more mechanical in it activities. It would seem worthwhile to attempt to understand why the public agricultural research system is becoming increasingly irrelevant to the concerns of broader society yet clings to traditional ways of doing things. It would be important to know at what point social dissatisfaction and decreased funding will induce substantial change. Finally, it would be important to anticipate what induced change will imply and how alternatives to funding reductions might improve the change process and product in light of the public interest. Understanding the dynamic public interest and informing

public institutions about that interest and the public about the potential of its institutions requires greater general knowledge of the entire system of human interactions encompassing agricultural and resource research.

## Conclusion

A unprecedented opportunity exists for The University of Florida, IFAS, and the SWFREC to develop a truly innovative approach to agricultural research and extension in southwest Florida. The center could provide a new model for the rest of the state and the nation. Both the time and the place seem to be ripe for change. Nationally, questioning of the traditional "experiment station" approach with the primary objective of production enhancement is increasing. This is because of adverse impacts that have resulted directly and indirectly from limited consideration of the broader resource use context. Southwest Florida appears, for social and ecological reasons, to be a location which may be particularly intolerant of the commercial agricultural production orientation of the traditional model. Both agricultural technology and agricultural research institutions have the potential for a much higher degree of compatibility with the ecosystem and the social system respectively.

The impetus for institutional innovation could come internally from policy makers in IFAS or could be imposed by external forces such as the legislature or the courts. The type of change that may be generated internally is

potentially more beneficial to IFAS, the agricultural sector in Florida, and the public at large than the type of change that might be imposed from the outside. A consideration of the "new agenda" for agricultural research may be a good place to begin the plan for change. Whether at the regional or state level, the innovation process could start with the inclusion of nontraditional groups, along with the commodity producer constituency, in the research and education planning process. Addressing the concerns of non-traditional groups (e.g. environmentalists, farm laborers, consumer advocates) may require a change in the orientation of academic disciplines as well as broader inclusion of less conventional disciplines in the IFAS framework. Resistance to change should be expected and will be overcome only with time, patience and deliberate institutional change. Change needs to be a normal part of institutional evolution. The agricultural research paradigm, that was widely judged successful in the 1950s and 1960s, while far superior to that earlier in the century, cannot reasonably be expected to maintain its performance in the highly dynamic environment of the 1980s and beyond. Ultimately, if institutions and the professions housed therein do not change to meet the needs of society, they are doomed to irrelevance and extinction.

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# BIOGRAPHICAL SKETCH

James D. O'Connor was born in Somerville, Massachusetts, on July 14, 1955. He attended the University of Notre Dame and received a Bachelor of Arts degree in government and international studies in 1977. He returned to graduate school in 1982, after having spent five years in Africa working with Catholic Relief Services. He was awarded a Foreign Language and Area Studies Fellowship at the University of Illinois and in 1984 received a Master of Science degree in agricultural economics. He came to the University of Florida in 1985 on a Farming Systems Research Assistantship to pursue further studies in agricultural economics and related disciplines.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Chris Andrew, Chairman
Professor of Food and Resource Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Jose' Alvarez
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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